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The role of questions in the physics laboratory classes of two non-native speaking teaching assistants

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**The role of questions in the physics laboratory classes of
two non-native speaking teaching assistants**

by

Janet Maureen Searls

A Thesis Submitted to the
Graduate Faculty in Partial Fulfillment of the
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CHAPTER 1. INTRODUCTION

Questions play an important role in science laboratory classes. This conclusion was reached following several observations of science and engineering labs at Iowa State University. Almost all interactions involved questions, and some dialogs seemed to contain even more questions than statements. The students and teaching assistants asked each other an impressive number of questions in various forms and for various reasons.

This case study of two introductory physics labs is an outgrowth of observations made for the Graduate College at ISU. It focuses on the questions asked by the international teaching assistants (ITAs) in charge of the labs as well as those asked by their students. Some situations and student attitudes that ITAs might encounter in the laboratory classroom will also be touched upon.

There is more than one reason for doing a case study rather than a strictly quantitative research project. Case studies are highly descriptive and allow close examination of information that might not be considered statistically relevant in a quantitative analysis. A large amount of data, even if fragmentary, gathered from a limited source can provide useful, detailed information in a qualitative analysis and suggest areas for future research. The two physics labs used in this study were chosen for having the same speech situation—same laboratory experiments, equipment, and

environment—thus reducing possible variables.

Why be interested in the spoken discourse and activities of ITAs in science labs at all? First, a large number—approximately 60% (Myers and Plakans, 1991)—of graduate teaching assistants (native and non-native speakers) at ISU, as at other universities, are placed in charge of lab sections in their major field of study. Although the duties of lab TAs differ widely between disciplines and levels, a common denominator of lab classes is the one-on-one interaction between TA and student, with the greatest emphasis on questions.

A second point of interest in looking at the discourse and activities in lab classes is that many Iowa State ITAs who marginally pass the English screening tests (SPEAK and TEACH) are placed in labs when their level of English is considered too low for a position as a recitation TA. It is questionable whether their level of proficiency is adequate for a lab position either. Furthermore, those ITAs who do not pass the screening test are recommended to take English 180, a course designed to improve spoken English and teaching techniques for American university classes. Almost all of these ITAs are then assigned to labs. Are they getting the preparation they need for their teaching assignments?

The TEACH test, like the English 180 course, has a design closer to a recitation class than a lab class. The ITA is given approximately 24 hours to prepare a five-minute presentation on subject matter which is provided. Following the five-minute lecture, the student questioners in the “class” have three minutes to ask questions related to the content of the material presented by the ITA or related to the classroom (e.g., Do you give pop quizzes?). The ITA is not expected to ask questions of the class and has little opportunity for the kind of one-on-one interaction found in the

two physics labs observed for this study. The three-minute questioning period does allow for negotiation of meaning by the ITA and “students,” which is typical of lab discourse, but the content questions are all directed toward what the ITA has presented, not what the student is trying to do.

The apparent need in the area of ITA training to explore the form and function of questions as found in a science lab context is the basis of this case study. The opportunity in ITA training to influence the questioning techniques of ITAs puts the focus of this study on the questions asked by the two ITAs observed.

CHAPTER 2. LITERATURE REVIEW

Relevant research to the topic of the role of questions in two physics labs taught by ITAs can be found in a variety of areas. The following are included in this chapter:

1. the "foreign TA problem,"
2. qualitative research and ethnographic methodology,
3. question forms and functions,
4. questions in science teaching, and
5. native speaker-non-native speaker (NS-NNS) interactions.

The "Foreign TA Problem"

The "foreign TA problem," as described by Bailey in an article of the same name (and addressed by numerous others also in Bailey et al., 1984), may be found at many large universities which employ international teaching assistants (ITAs) as instructors of a great number of undergraduate courses. These ITAs very often have difficulty in speaking English, and this problem extends beyond their oral proficiency into the realm of cultural differences and expectations. Compounding the problem may be an increasing ethnocentric perception held by American students who are also demanding what they and their parents consider to be their rights as "consumers" of a college education. Merriam (1988) writes specifically about the situation in science departments at large research universities where professors are valued for their research capabilities not teaching. With professors devoting more of their time

to research, the teaching load of undergraduate classes is left increasingly to graduate teaching assistants, many of whom view this position as a necessary means of support while in school but irrelevant to their future as scientists. Moreover, fewer and fewer American students are entering graduate school or, consequently, becoming teaching assistants. This is not indicative of an overall decline in the number of graduate students in the sciences; rather, international students are filling in the empty spaces. As many as "25.6 percent of all science and engineering graduate students" in the United States in 1985 came from outside the United States (p. 104). The low status of teaching combined with an increase in non-native speaking graduate students becoming teaching assistants very likely contributes to the "foreign TA problem."

Bozack (1983) more specifically addresses the role of the teaching assistant in physics. He states that because of the high amount of contact between physics students and TAs in undergraduate classes, "student attitudes toward physics and physics teaching could depend more on the TA than the lecturer or professor" (p. 21). Consequently, when learning physics is complicated by having a large portion of classes taught by ITAs "who initially have some difficulty with the language" (p. 22), student attitudes toward physics AND ITAs could be negative, especially since American students place such a high importance on grades (more so than on actual learning) (Kandel, 1989), and ITAs can easily be blamed by students for their own lack of understanding and/or poor grades.

It seems unlikely that the trend of using ITAs to teach undergraduate courses at large research universities will change in the near future. The point, then, is to improve the existing situation so that the benefits of international educational exchange

will be recognized and disadvantages lessened. This means not only improving the spoken English skills of ITAs, but providing them with training in American university classroom culture and teaching as well. Students, too, should be made aware of what they can do to facilitate understanding and communication with their ITAs. Perhaps they could learn better question-forming and listening skills and suspend judgment on an ITA's speaking ability for the first couple of weeks.

It seems more likely under the current system, however, that the ITAs' expectations, teaching techniques, and spoken English will be influenced than the students' expectations, attitudes, and learning techniques. Consequently, the focus of this research with regard to the "foreign TA problem" is on the ITAs and possibilities of better preparation for teaching assignments in the laboratory classroom.

Qualitative Research and Ethnographic Methodology

Qualitative research, with well documented procedure and analysis steps, can produce insightful and highly descriptive studies. According to Miles and Huberman (1984), making note of each step taken during each part of the research project leading up to the conclusions drawn makes qualitative research more reliable and gives other researchers an opportunity to better test the results. Also, with some idea of what to expect in the study, the focus of the research can be narrowed so as to include numerical data to support the descriptions without restricting the research so much that important, non-numerical observations are left out.

An ethnographic methodology goes hand in hand with qualitative research. In using ethnographic methodology, the language researcher goes out into the field of naturally occurring language much as an anthropologist going into a foreign culture

to collect data. Although the research cannot be as scientifically controlled as in experimental studies, there is great value in obtaining language in its natural context, particularly if the results are meant to be applied to that setting. Van Lier (1988) gives the following rationale for ethnography:

1. our actual knowledge of what goes on in classrooms is extremely limited;
2. it is relevant and valuable to increase that knowledge;
3. this can only be done by going into the classroom for data;
4. all data must be interpreted in the classroom context, i.e. the context of their occurrence;
5. this context is not only a linguistic or cognitive one, it is also essentially a social context. (p. 37)

By increasing our knowledge of what actually happens in a classroom (particularly in laboratory classrooms, with respect to ITA training), we will have a better idea of what "improvements" to try.

Question Forms and Functions

Before examining the forms and functions of questions, perhaps some definition of the term "question" should be given. Churchill (1978), following Bolinger (1957), uses four criteria—of which one or more is necessary—to determine a question:

1. It has interrogative distribution. The fact that an answer has occurred following an utterance can often be used to infer that a question elicited it.

2. It has interrogative syntax...
3. It has interrogative intonation...
4. It has interrogative gestures... (p. 29)

However, these criteria seem to be incomplete in that a hearer, who does not have the advantage of the first criterion by which to judge a question, sometimes recognizes an utterance as a question even though it does not meet any of the other criteria. For example, a statement made in a phone conversation such as "I was wondering if you had received the package I sent" would very likely elicit a response of yes or no. This can be considered a "hidden" type of question, whose interrogative quality depends primarily on its lexical aspect and the speech situation. Some statements have an interrogative quality, but they may or may not be interpreted as questions.

Both Goffman (1976) and Merritt (1976) examine the place of questions in conversation, as the first part of an adjacency pair. The adjacency pair idea follows the same thinking as Bolinger's first criterion: A question is followed by some kind of response. As Goffman notes, sometimes the meaning of the answer depends on the question. For example, "Eleven" makes perfect sense when following the question "How old are you?" (p. 258).

Merritt discusses the occurrence of questions following questions in service encounter dialogs, where the answer to a question may be delayed by another question ("embedding" or "call for replay") or superseded ("elliptical coupling"). An example of embedding, borrowed from Merritt, is as follows:

C: (Q1) May I have a bottle of Mich?

S: (Q2) Are you twenty-one?

C: (A2) No.

S: (A1) No.

A call for replay such as "What?" or "Excuse me?" asks for a repetition of the first question before an answer can be given. Elliptical coupling is actually a type of response. For example, if a customer asks, "Can you give me change for a dollar?" and the person at the cash register says, "All quarters?" it is understood that the answer to the first question is yes.

A question, then, can be seen as an utterance which has interrogative quality and/or which expects an answer of some sort to follow eventually. This definition implies that what is considered a question may vary widely in its form and function.

A great deal of literature has been written on the forms and functions of questions. The research on which this study is based will be presented here; the final taxonomies of question forms and functions used in this research project will be presented in detail in the next chapter.

Kearsley (1976) devised a logical taxonomy of question forms "based mostly on syntactic criteria" (p. 357), which provided a basis for the question form categories used in this study (see Figure 2.1). His taxonomy initially splits verbal from non-verbal questions. The non-verbal category is further divided into overt (e.g., raised eyebrows) and covert (questions asked and answered in one's own head). The verbal category has more complicated subdivisions.

The first subdivision of verbal questions is between indirect and direct. Indirect questions are actually declarative in form, but interrogative in function. In Kearsley's taxonomy they contain an embedded WH phrase (e.g., I wonder why they left early). Direct questions are either open (WH) or closed ("multiple choice"). Open

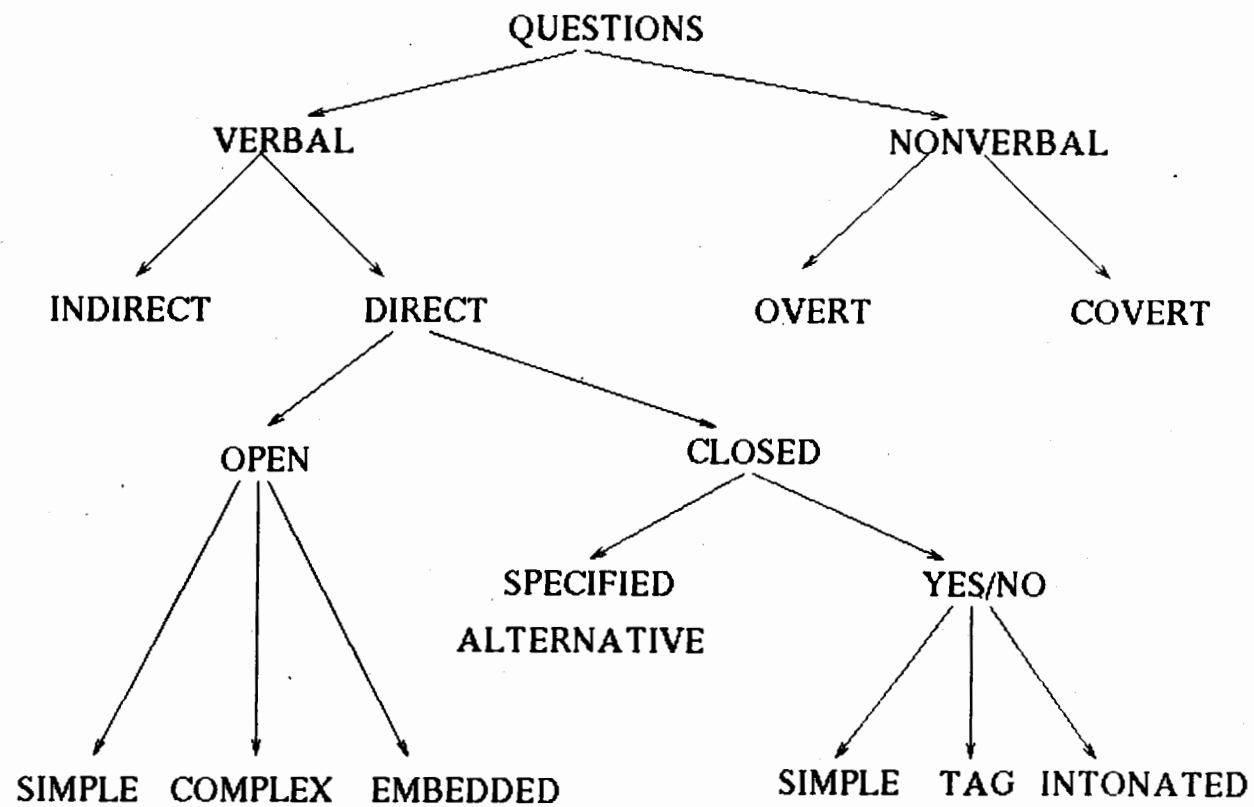


Figure 2.1: Question Forms (from Kearsley, 1976)

questions are divided into simple (containing one Q-marker), complex (more than one Q-marker), and embedded. Closed questions are divided first into specified-alternative (or-choice, e.g., Do I turn left or right?) or yes/no, and then under yes/no into simple (initial auxiliary), tag (inverted auxiliary at end), and intonated (uninverted with rising intonation).

Kearsley also formed a taxonomy of question functions (see Figure 2.2), which was comprised of four, not mutually exclusive, categories: echoic, epistemic, expressive, and social control. Echoic questions ask for repetition or for confirmation of understanding. Epistemic questions seek information and are subdivided into the categories referential and evaluative (display). Referential questions request information unknown by the speaker, whereas evaluative questions request a display of knowledge from the hearer of what the questioner already knows. Expressive questions give attitudinal information such as surprise or doubt. Social control, a category not used in this project, is divided into two subcategories: attention and verbosity. Attention questions allow the questioner to take control of the conversation. Verbosity questions are polite conversation sustainers such as might be found at a cocktail party.

Three categories from Long and Sato (1983) were added under Kearsley's echoic division to deal more specifically with classroom discourse: comprehension checks, clarification requests, and confirmation checks. Long and Sato's situation was the opposite of the present one in that the teachers were native speakers and the students non-native speakers of English. They make the distinction, for example, that comprehension checks are made by a native speaker (the teacher). However, there is no reason why these categories cannot apply equally to native and non-native speakers,

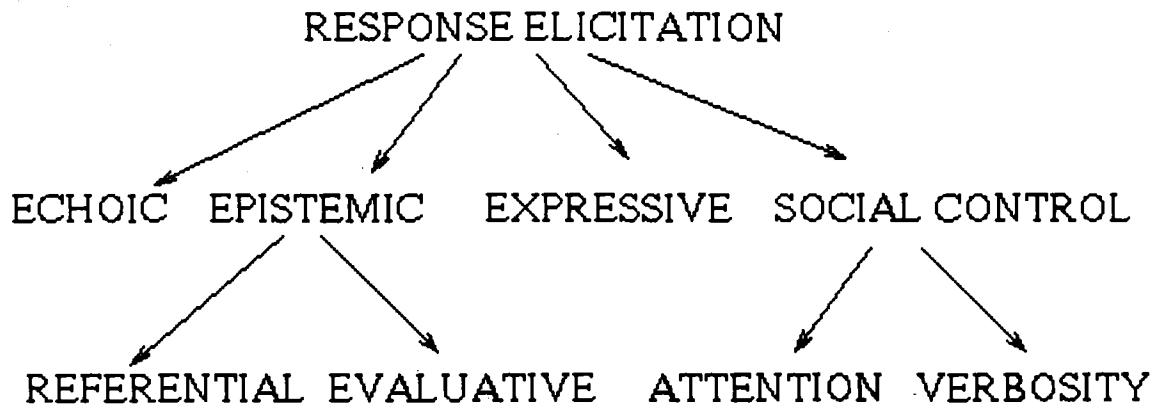


Figure 2.2: Question Functions (from Kearsley, 1976)

students and teachers.

Questions in Science Teaching

As Bonnstetter (1988) says, "learning is not a spectator sport....Science entails questions, and questions suggest responses and action" (p. 95). This view of questions in science teaching is not new. Questions have for decades been considered to play a vital role as teaching and learning devices in science classes, particularly labs, a point made very well in an editorial originally written in 1963 by Sutton (1974). In his opinion, being able to ask thought-provoking questions of students along with encouraging student questions by responding to them well can do much to alleviate "the saddest disease in our whole educational process... the atrophy of curiosity, inquisitiveness, and the eager asking of questions" (p. 374). Paldy (1988), in an editorial about his resolutions to improve his course, writes that he "would ask more

questions and provide fewer answers in class, try to build in opportunities for students to participate more actively" (p. 7). Along the same lines, Koser (1988) states that besides asking students thought-provoking questions, he likes to respond to student questions "with a directed question, which, if understood, will lead to a desired result" (p. 38).

The importance of questions and teacher-student interaction in science labs has also been noted in research done in the field. However, Kyle, Penick, and Shymansky (1980) found in a descriptive study of instructor behavior that the instructors spent very little time asking their students questions or even answering them.

Myers and Plakans (1990), on the other hand, found that many questions were asked both by ITAs and students in five labs observed. Two of the five ITAs in the study, who actively asked questions to help communication and to get students to think more about what they were doing, had more success in relating to their students and teaching effectively. Myers and Plakans suggest that ITAs be given training in using questions to negotiate for meaning as well as to help students understand the underlying concepts of their lab work. To do this, the ITAs ought to be made aware of what types of questions will elicit the desired responses from their students and practice using them.

In general, the importance of asking students well formulated, thought-provoking questions in science classes and allowing students plenty of time to think and respond is a given. Under the right conditions, good questions can get students to participate more actively in class and help students develop critical thinking skills. The mission, then, in science teaching—perhaps in education as a whole—is to teach students to question effectively and "to solve real problems, not regurgitate facts" (Bonnstetter,

1988, p. 97). In other words, help students develop critical thinking skills so that they can use their own ideas to solve new problems. As Pestel (1988) puts it, students need teachers "to ask them the appropriate series of questions that will teach them to discover answers for themselves" (p. 27).

Although the general consensus seems to be that asking students higher cognitive level questions (based on Bloom's taxonomy) is desirable to get students more involved in learning and to develop their critical thinking skills, there is some reservation on the part of more than one author interested in the use of questions in the classroom. Farrar (1988), in "A Sociolinguistic Analysis of Discussion," asserts the need for further examination of the practice of coding questions as either higher or lower level. She gives the example that "questions may simultaneously ask a lower level question explicitly and a higher level question implicitly" (p. 70). Other factors in questioning also need to be examined such as the relative importance of the question topic, the level of response compared to the level of question, the relation between the length of a response and the level of thinking required to give it (longer is not necessarily better), and the effectiveness of one higher level question versus a series of lower level questions.

Specifically in the area of chemistry labs, Johnstone (1989) argues that from what we know of the psychology of learning, students in introductory labs have all they can handle to manipulate the equipment and follow lab instructions like a cookbook recipe; the working memory is already in danger of being overloaded without requiring deep thought in addition. In other words, allow students to learn the skills necessary for doing lab experiments before asking them to interpret what is happening and relate it to theory. For Johnstone, training ITAs to ask their students higher cognitive

level questions with the purpose of teaching or checking their understanding of related theory would be pointless until the students have mastered the basic procedures of the lab.

In contrast, Klinzing and Klinzing-Eurich (1988), while admitting that "the correspondence between the cognitive levels of teacher questions and student responses is low" (p. 217), recommend that teachers consistently use higher level questions, at least in classroom discussions, since ultimately the overall cognitive level of student responses will rise.

For teacher questions—no matter how well phrased or thought provoking—to be effective in inducing a higher level of thinking in students, it is necessary that students be given ample time to think and formulate a response. The necessity of "wait time," the pause between a question and its response, has been alluded to or specifically addressed by many researchers and educators, both in the area of science education and education in general (Orear, 1979; Andrews, 1980; Bonnstetter, 1988; Pestel, 1988; Swift, Gooding, and Swift, 1988, to name a few). Most teachers do not allow enough wait time, perhaps thinking that their questions are not worded well or not realizing how much time is needed for students to respond to "challenging" questions (Andrews, p. 133). Even teachers who have been trained in effective pausing have difficulty maintaining a long enough wait time over an extended period of time (Swift, Gooding, and Swift, p. 207). Furthermore, it is not adequate to simply allow a long pause after a higher level question; teachers must maintain eye contact with their students, letting them know nonverbally that their answer is important (Bonnstetter, p. 96-97).

In spite of some reservations, it is generally agreed, then, that thought-provoking

(i.e., higher level) questions combined with an appropriate use of wait time are desirable in science teaching to increase students' mental engagement and consequently their learning.

Native Speaker-Non-native Speaker (NS-NNS) Interactions

Whether it is "foreigner talk" (Long, 1982 and 1983) or increased use of echoic questions, there are quite often differences between NS-NS and NS-NNS conversations. Some differences noted by Varonis and Gass (1985) and Gaies (1982) include an increase in clarification requests and confirmation checks as well as expansions and elaborations. Native speakers usually recognize a lack of shared background and expect a lower level of language ability in the non-native speaker. A study by Varonis and Gass (1982) of encounters between NSs and NNSs (or assumed non-natives) who were asking for directions showed that most often the NS did a confirmation check before answering the question, even when the question was perfectly grammatical and intelligible despite a noticeable accent.

Rounds (1987) discusses the aspects of effective versus ineffective teaching by NS and NNS TAs in five math classes. Included in the article is a section on the interactive function of questions. The point is that when a TA asks a question, he or she "recognizes that there is someone to respond and moves away from the model of the mechanical problem solver" (p. 664). She also notes that questions can have the function of marking a "milepost" in a problem and of giving feedback to the teacher on how well the students can apply what has already been taught. Although the findings of her study apply to both NS and NNS TAs, the purpose is to improve communicative competence of NNS TAs through materials that meet their

specific-purpose language needs.

A review of the literature suggests that the use of ITAs in more and more undergraduate courses has caused some problems at large research universities with American students who are unaccustomed to communicating with people from other languages and cultures, particularly in a classroom setting. A descriptive study of interactions in these classroom settings can provide valuable information in an area where research is limited. By observing laboratory classroom interactions, a better understanding of what the majority of ITAs may encounter in their teaching assignments at Iowa State University would be gained. The literature also suggests that questions are considered important tools in science education and in communication between native and non-native speakers. A closer examination of question forms and functions for both of these purposes might prove to be very useful in ITA training.

CHAPTER 3. METHOD

Subjects

The primary subjects of this study were two physics ITAs teaching introductory labs for non-majors. Both were male and in their mid-twenties. One, a native speaker of Chinese, had taken the English course (180) for ITAs to help improve English skills and teaching techniques in American university classes. The other, a native speaker of Korean, had not. Although the Chinese speaker (hereafter known as TA1) had completed the course the previous semester, his spoken English was still not quite up to the level of the Korean's (TA2), whose speech in fact tended to be slower than TA1's. In spite of being a little harder to understand, TA1 seemed friendlier and more outgoing than TA2, who acted more reserved with his students and rarely even smiled. In fact, TA2 admitted to feeling some distance between him and his students, caused, as he perceived it, by his inability to joke in English.

Although the focus of the research is on the questions the ITAs asked their students, also of interest and included in this case study are the questions the students asked their ITAs. Therefore, the secondary subjects are the students who attended the labs on the two days of observation. Thirteen students were present at TA2's Wednesday afternoon lab, and eight out of eleven showed up for TA1's Friday afternoon lab. These 21 students were undergraduates, many juniors and seniors, and

a large majority—according to the ITAs—pre-architecture students required to take the Physics 111 lab. Males outnumbered females (16-5), and native speakers of English far outnumbered non-native speakers (20-1), but no formal data on the students were gathered.

Procedure

Data collection was carried out in connection with a larger project sponsored by the Graduate College at Iowa State University. (Conclusions from the larger study are reported in Myers and Plakans, 1990, 1991 and Myers, 1991.) After a futile attempt to classify the questions “live” as they were asked during a previous lab observation, the need to preserve the discourse for later analysis was recognized and a hand held tape recorder put into use. Thus, the data base for this research came from the tapes recorded while observing the two Physics 111 labs for the Graduate College. Additional information was provided by the ITAs during interviews which followed the observations and centered on a questionnaire developed by two other researchers for the Graduate College’s project.

The two labs providing data for this research were observed during the same week, one on Wednesday, 19 April 1989, and the other on Friday, 21 April. These two-hour labs both started at 4:10 p.m. and covered the same experiments on “The Reflection and Refraction of Light” (laser beams through lenses and plexiglass blocks). (See Appendix B.)

The ITAs also taught their labs in the same classroom, which was set up with tables coming out from the side walls with two movable chairs per table initially facing the front of the room. The students were able to arrange themselves into

groups of two to four at a table to work on the experiments. Most equipment for all the experiments of the day was located at each table but needed to be assembled by the students. In the center of the room were a slide projector stand and two tables, with extra equipment, set perpendicular to the other tables. At the front of the room was the teacher's desk and behind it a screen.

Each Physics 111 lab began with a ten-minute slide and tape presentation, which had been made by the physics TA supervisor to explain the use of equipment and the experiments to the students as well as to make note of any hazards involved. TAs, therefore, did not need to make a presentation to the class themselves, and the students in all sections had the same opportunity to see what to do during the lab. After the slide show, both ITAs turned on the lights again, made brief announcements to the class as a whole, and then began circulating. For the rest of their respective lab periods, they walked around the room asking and answering questions, shadowed by the researcher carrying a hand held tape recorder.

The tapes, which equal approximately three hours total, were transcribed using an Onkyo TA-2022 tape deck and TX-41 receiver and Yamaha HP-3 headphones. Only conversations which involved the ITAs were transcribed, each according to the different speakers of that dialog (where discernible) and including indications of any overlaps and interruptions of speech (see Appendix A). No attempt was made to transcribe phonetically either the ITAs' or the students' speech except in a few instances where it was impossible to reasonably judge which of two words was intended (e.g., reflected/refracted). Although some student questions directed to other students were included in the transcripts for the sake of context, these questions were not counted in the data. Interrupted questions were also omitted from the data base.

The transcripts were checked and approved by another listener.

Data

The data consist of the questions asked in the interactions between the two lab ITAs and their respective students and excluding incomplete or indeterminate questions. The remaining corpus of questions was categorized both by form and function.

There are probably as many systems of categorizing as there are researchers attempting to do it. Both the system for syntactic form and for function used in this study are based largely on Plakans' (1987) taxonomies, which are initially based on those of Kearsley (1976) with modifications primarily from Long and Sato (1983). I in turn have made modifications to suit the requirements of this study, including a form category from Byrd, Constantinides, and Pennington (1989) and some form and function categories based on Celce-Murcia and Larsen-Freeman (1983) and their presentation of additional tag question functions from Brown (1981).

Form

With respect to syntactic form, the questions in this study are divided into two classes: indirect and direct. These two major headings are subdivided as follows:

1. Indirect

- (a) Declarative with WH—a statement which includes a question marker (Q-marker) (e.g., S: "I don't understand... what they're looking for.")

- (b) "Hidden"—any statement which indicates confusion or suggests a need for confirmation of understanding but does not include a Q-marker (Byrd, et al.) (e.g., S: "But I thought it wasn't supposed to end up a line.")

2. Direct

(a) WH (Open)

- i. Simple WH—only one Q-marker (e.g., TA: "For this case what are you observing?")
- ii. Complex WH—more than one Q-marker (e.g., S: "How do you know how far away to make it—put it, you know, to make it parallel?")
- iii. Uninverted WH—in general, rising intonation and Q-marker following the verb (e.g., TA: "You— you cannot figure out what?")
- iv. Elliptical WH—part of the question deleted but requesting same type of response as other WH questions (e.g., S: "Is the focal length supposed to match up with the number [on] the lens?" TA: "Match?" (Elliptical WH which could be phrased as "What does 'match' mean?") S: "Is it supposed to be the same?")

(b) Yes/No (Closed)

- i. Simple Yes/No—initial auxiliary (or inverted BE or HAVE); rising intonation (e.g., TA: "Do you understand?" or S: "Am I right?")
- ii. Tag—statement with appended "short question" that seeks confirmation; either rising or falling intonation (e.g., S: "So it's 50 away, isn't it?" or TA: "Usually we take average of all this, right?")

- iii. Intonated (Uninverted)—statement with rising intonation (e.g., S: "That would be straight through that way?")
- iv. Elliptical—missing auxiliary (and/or other parts); rising intonation (e.g., S: "Longer than two hours?" meaning "Will the lab take longer than two hours?")
- (c) Specified Alternative (Or-Choice)—"multiple choice" of a combination of yes/no questions joined by "or"; will not take yes or no for an answer (e.g., S: "Is that five or is that zero...")

Of course, not all questions fit neatly into the prescribed categories. An interesting question pattern, which has no place in the above taxonomy, is a combination WH and either yes/no or specified alternative (either one possibly elliptical). Usually it begins with an open question (WH) and then adds a possible response or responses so that it is most often answered as a yes/no or specified alternative question, though not always. Because this type of question seems to be fairly common in the data, another category was added:

- (d) Combination (Open and Closed)—contains both a WH question and either a yes/no or specified alternative (yes/no or specified alternative can be complete or elliptical); either part can be answered (e.g., S: "What is it, one over sine 45?" or S: "...which way are they talking about, this way or this way?")

A less common twist on this is starting out with the closed question (yes/no or specified alt.) and tacking the WH question on at the end (e.g., TA: "The index of refraction should be greater than one or smaller than one, what do you think?").

Some informal or “nontraditional” WH words—Hm? Huh? Sorry?—are categorized with the usual WH forms simply because they elicited the same type of response as “What did you say?” Although Luthy (1983) concludes that the meanings of “‘nonlexical’ intonation signals” such as uh-huh and huh? are sometimes not understood by non-native speakers of English, the two ITAs in this study had no difficulty with those occurring in the lab discourse. In fact, TA1 frequently used the form “Hm?” himself to request clarification.

The elliptical yes/no and WH categories are expanded versions of the ones found in The Grammar Book (Celce-Murcia and Larsen-Freeman, 1983), in which elliptical questions have a deleted auxiliary but are otherwise intact. Two of their examples, one from each category, are “(Are) you going to the movies? (p. 116)” and “What you doing? (p. 154),” which often sounds like “Whatcha doin’?” This type of ellipsis of the auxiliary occurred in the data for this research, but more often whole phrases were deleted, especially when the missing information could be understood from what had been said earlier. Often parts of speech other than the auxiliary were left off when partial repetitions of previous utterances were made (e.g., TA: “It doesn’t matter.” S: “Doesn’t matter?”). In effect, the two elliptical categories used in this study include any uninterrupted questions that have any of the usually necessary parts of speech deleted, whether it be the auxiliary, subject-noun phrase, whole verb phrase, or even—in the case of WH questions—the Q-marker. (Note: Questions consisting of a single Q-marker and nothing else, “Why?” for example, are counted as simple WH questions; whenever it was unclear whether a question’s form was intonated (uninverted) or elliptical, the question was classified as intonated.)

Occasionally, questions occurring in natural speech defy classification by form. For example, when a student voices an attention seeking query such as "Sir?" to focus the TA's concentration to what he is saying, it must be dealt with individually.

Function

The main focus of this thesis is on the function of the ITAs' questions, and it was in classifying the questions by function that caused the most difficulty. How does one know, when analyzing a question, what the speaker intended when asking it? There are some clues, based on accepted practices within a society, that allow the hearer to determine the probable intent and to make, in general, an appropriate response. Some clues are in the combinations of form, word choice, intonation pattern, tone of voice, and context. However, there is still plenty of gray area in which to lose oneself with the query, "What was the speaker's actual purpose in asking that question?"

Joined to the problem of deciding what was going through another person's mind which would prompt a certain question is the problem of determining in which category the question best fits. Admittedly, the categories used in this study have "soft" boundaries, which allow some questions to fall into more than one category. It should be noted also that questions often have more than one function. Where this was the case, the function which seemed to be most important was chosen.

The fourteen categories used in this case study are a rather eclectic assortment, but are drawn primarily from Kearsley (1976), Long and Sato (1983), and Plakans (1987). They can be divided into three major groups with subdivisions as follows:

1. Epistemic—Generally speaking, the primary function of epistemic questions is to seek information.

- (a) Display (Evaluative)—requests information that is already known by the questioner. This type of question is quite common in the classroom setting and has the basic purpose of testing the hearer's knowledge or understanding. Because it is uncommon in adult-to-adult speech, it is not recommended as a teaching device in the language classroom. However, it can be (and is) used in a lab situation to get students to be more actively involved in or to think more about what they are doing. An example specific to this study is TA2 asking a student, "...what is the uh angle of refraction?" when he can see for himself what their angle of refraction is.
- (b) Referential—Referential questions request information that is unknown to the questioner and of real interest (as opposed to questions whose function is to carry on polite conversation). For example, a student in TA1's lab asked, "How exactly um, do you calculate index of refraction?" He had a real interest in finding out since the information was required to complete the lab report.
- (c) Verification—The verification request can be thought of as a request for reassurance of comprehension of information which has been obtained previously. It is not always possible to distinguish between verification requests and referential questions which are guesses in question form. Where there was doubt, most were classified as referential. In the following example, a student in TA2's class asks a hidden question to verify a previous statement made by TA2:

TA:...and then you put another lens. This is just for make the ray

parallel. You're not investigating the focal length of this. ...

S1: So now we're gonna put another one in after it.

TA: Right.

- (d) "Fill-in-the-blank"—This subcategory has been added to deal with elliptical questions which are added onto another speaker's utterance. The questioner's apparent purpose is to check (or perhaps show) his/her own understanding of what the other speaker is saying by attempting to complete that person's sentence, but with rising intonation.

TA:...and in that case you have to measure the angle, but for
this case—

S1: Doesn't matter?

2. Echoic—Questions in this category have the common purpose of making an utterance heard and/or understood. The six subcategories included here are confirmation check, clarification request, comprehension check, repetition, rephrasing, and expansion/addition.

- (a) Confirmation Check—usually a short repetition, whole or in part, of what another speaker has said. Its function is to check the questioner's hearing or comprehension of the previous speaker's utterance. The following dialog contains a student's confirmation check in response to the ITA's display question:

TA:Then what is— what is the uh angle of refraction? For this
case?

S1: The angle of refraction?

- (b) Clarification Request—the questioner's attempt to understand another person's information or simply to hear it correctly. Some clarification requests are epistemic in function, but in this study no distinction is made between echoic and epistemic. (Plakans (1987), however, did have a separate category for each in her thesis.) A typical clarification request is "What'd you say?"
- (c) Comprehension Check—a way for the questioner to find out whether the hearer has understood what the questioner said. Quite often it comes in the form of a tag at the end of a statement, especially the words "right" and "OK." Some teachers use this technique frequently when explaining material, as did TA1. Here is a typical comprehension check from his class:
TA: So here, direction of normal actually is two, right?
- (d) Repetition—a question which is repeated because the hearer, for whatever reason, has failed to answer it the first time to the questioner's satisfaction. Sometimes it is made in response to a clarification request. A repetition does not need to be an exact repeat of the previous question, and this is where the boundary between repetitions and rephrasings is a little soft. (See example under Rephrasing)
- (e) Rephrasing—repeat with a change in wording of a question which, as in the case of a repetition, has not been answered satisfactorily or which is considered by the questioner to have been inadequately phrased. The following example taken from TA2's lab class includes first a repetition

and then a rephrasing in the ITA's final utterance.

TA: Yeah, then where is this beam from?

S1: It comes— it comes straight out, it looks like. You can see the line, I think.

TA: Where is this beam from? What kind of beam is this?

- (f) Expansion/Addition—This category has been added to take care of the partial questions which follow an initial question, sometimes even before the hearer has been given a turn to respond. The questioner recognizes either from the hearer's response or from his/her own monitoring before the hearer can respond that the original question needs some clarification. The example below has a referential question followed by two expansion/additions:

S1: How exactly um, do you calculate index of refraction? Using the uh, critical angle? That second technique?

3. Extra-interrogative—category of questions usually having the function of carrying extra information—beyond the actual question—to the hearer. The subcategories included here are rhetorical, directive, appeal, and expressive.

- (a) Rhetorical—not a true question in that it does not expect a response from the hearer. The response is either understood from the question itself or is supplied by the questioner. The example below is from TA2's class when he was working with some students on a problem regarding a graph of a line they had drawn: TA: Then you got a straight line. How can slope

change? (i.e. The slope of a straight line can NEVER change, so the students must have made an error somewhere.)

- (b) Directive—actually a request or “command” in the polite form of a question that the hearer do something. For example, TA2 saying to his student, “Can I see the graph?” could be written as “Hand me the graph, please,” and anything other than the action being carried out would seem strange or even rude.
- (c) Appeal—like referential questions but ask for permission as much if not more so than for information. The example taken from TA1’s lab concerns a student who brought the papers for the wrong lab experiments instead of the ones being used that day. S: Can I do it on paper? And bring the prelab in on- on next Friday or put it in your box?
- (d) Expressive—This type of question gives information to the hearer about the attitude or feeling of the questioner. Surprise, doubt, humor, or irritation can all be expressed in the form of a question. Some expressive questions are also rhetorical. However, as was stated earlier, questions often do have more than one function and are categorized in this study by which seems to be of greatest importance. The example here is from a dialog in which one student had successfully answered several display questions in a row asked by the ITA and finally countered with the humorous question: “So do I win?!”

All fourteen function subcategories used in this research are of interest in examining the role of questions in an introductory physics lab taught by an ITA, but of particular

interest are the questions which the ITA uses as a way of getting the students to think about what they are doing instead of just filling in the blanks to finish as soon as possible. These questions seem to be in the display and rhetorical categories. Also of special interest are the echoic questions, which are used by the ITAs and students alike to negotiate for meaning.

CHAPTER 4. ANALYSIS AND RESULTS

The main purpose of this study was to examine the form and functions of questions that occurred in the conversations between the two ITAs and their lab students. Because of the nature of the data, the analysis of the questions is intended as a description of tendencies only.

In TA1's Friday afternoon lab, the number of questions recorded totaled 295: 149 made by the ITA and 146 by his eight students (see Table 4.1). For TA1, the largest number of questions by far, 64, occurred in the comprehension check category. The next largest category was referential, with 29, followed by display, with 17. For the students, referential questions made up the largest group, 72. They also made 18 confirmation checks and 16 clarification requests.

TA2's Wednesday afternoon lab had a total of 331 analyzed questions: 130 from the ITA and 201 from his 13 students (see Table 4.2). TA2 asked his students 31 display and 21 referential questions. He also made 24 confirmation checks, 16 clarification requests, and 10 comprehension checks. The students asked 100 referential questions, as well as 25 confirmation checks, 21 clarification requests, and 22 rephrasings.

As is indicated by the questions counted, the two ITAs differ somewhat in their approach to teaching with regard to their use of questions. Both are more likely

Table 4.1: Question forms and functions of TA1

Functions	Forms												Tot	%
	D	H	S	C	U	E	Cb	SA	Si	T	I	El		
Disp	0	0	13	0	0	0	0	0	2	0	1	1	17	11
Ref	0	1	9	0	0	0	0	0	8	0	8	3	29	19
Ver	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FIB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conf	0	0	2	0	0	0	0	0	0	0	3	1	6	4
Clar	0	0	4	0	0	1	1	0	0	0	1	0	7	5
Comp	0	0	0	0	0	0	0	0	0	63	0	1	64	43
Rep	0	1	1	0	0	1	0	0	0	0	0	1	4	3
Rephr	0	0	2	0	0	0	0	0	0	2	0	0	4	3
E/A	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhet	0	0	3	0	1	0	0	0	0	1	2	1	8	5
Dir	0	0	0	0	0	0	0	0	4	2	0	0	6	4
App	0	0	0	0	0	0	0	0	1	1	0	0	2	1
Expr	0	0	1	0	0	0	0	0	0	0	0	1	2	1
Total	0	2	35	0	1	2	1	0	15	69	15	9	149	
%	0	1	23	0	1	1	1	0	10	46	10	6		100

D = Declarative

S = Simple WH

U = Uninverted WH

Cb = Combination (Open and Closed)

Si = Simple Y/N

I = Intonated (Uninverted) Y/N

H = Hidden

C = Complex WH

E = Elliptical WH

SA = Specified Alternative

T = Tag

El = Elliptical Y/N

Disp = Display

Ver = Verification request

Conf = Confirmation check

Comp = Comprehension check

Rephr = Rephrasing

Rhet = Rhetorical

App = Appeal

Ref = Referential

FIB = Fill-in-the-Blank

Clar = Clarification request

Rep = Repetition

E/A = Expansion/Addition

Dir = Directive

Expr = Expressive

Table 4.2: Question forms and functions of TA2

Functions	Forms													
	D	H	S	C	U	E	Cb	SA	Si	T	I	El	Tot	%
Disp	0	0	22	0	0	0	1	3	1	2	2	0	31	24
Ref	0	0	5	0	2	0	0	0	9	1	3	1	21	16
Ver	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FIB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conf	0	0	2	0	0	0	0	0	1	0	8	13	24	18
Clar	0	1	8	0	2	1	0	0	1	0	3	0	16	12
Comp	0	0	0	0	0	0	0	0	1	9	0	0	10	8
Rep	0	0	3	0	0	0	0	1	1	0	0	0	5	4
Rephr	0	0	3	0	1	0	0	1	0	0	0	1	8	6
E/A	0	0	2	0	0	1	0	1	0	0	0	1	5	4
Rhet	0	0	3	0	0	0	0	1	0	3	0	0	7	5
Dir	0	0	0	0	0	0	0	0	2	0	0	0	2	2
App	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Expr	0	0	0	0	0	0	0	0	1	0	0	0	1	1
Total	0	1	48	0	5	2	1	7	18	15	18	15	130	
%	0	1	37	0	4	2	1	5	14	12	14	12		10

D = Declarative

S = Simple WH

U = Uninverted WH

Cb = Combination (Open and Closed)

Si = Simple Y/N

I = Intonated (Uninverted) Y/N

H = Hidden

C = Complex WH

E = Elliptical WH

SA = Specified Alternative

T = Tag

El = Elliptical Y/N

Disp = Display

Ver = Verification request

Conf = Confirmation check

Comp = Comprehension check

Rephr = Rephrasing

Rhet = Rhetorical

App = Appeal

Ref = Referential

FIB = Fill-in-the-Blank

Clar = Clarification request

Rep = Repetition

E/A = Expansion/Addition

Dir = Directive

Expr = Expressive

to let the students initiate a dialog than to interrupt the students with a question. However, once the dialog has been started, TA1 tends to give a short, direct answer to a student's referential question and then explain further using comprehension checks, almost always in the form of tag questions, whereas TA2 has a tendency to respond with a short answer followed by a display question. Another difference between the two ITAs is use of confirmation checks and clarification requests. TA2 is much more likely to check his understanding of students' questions and request clarification before responding than is TA1. (Compare 18% confirmation checks and 12% clarification requests for TA2 to 4% and 5% respectively for TA1.) Consequently, conversations between TA2 and his students include more rephrasings of questions by the students than in TA1's lab.

The following dialogs selected from the data will serve as examples of interactions between the ITAs and students in their physics labs, focusing on the uses of questions. The ITA may encounter a wide variety of situations and student attitudes in the lab class contained in many different forms of speech. An awareness of possible linguistic and classroom situations could be helpful to the ITA preparing to teach a science lab.

The first dialog below is a fairly typical example of teacher-student exchanges in TA1's lab. The conversation is initiated by a student with a referential question. TA1 responds with an explanation using comprehension checks. (TA1 side A 33:41)

S1: So, where do we measure from? OK, it's 59, but do we measure
from [...]

S2: [[Oh, measure from the normal?]

TA:No. Here i(s) the direction. [We call it] direction is

- just- just what do you read? 59 or 60, right? So that's the direction. Then direction of normal, so this is normal, normal is 30 degrees, right? It's 120 minus 90 degrees is 30 degrees, so the direction of s- the normal is 30 degree. Then the angle of- of refraction [in]- that means between- refract means [n] normal, right? So [... angle]. [An] incident [and] zero. So incident angle is incident ray between- between the incident ray and the normal. So [you? we?] go down here. And 59, 5
- S1: 59
- TA: Yeah. And this is 30. Angle of incident- incident is zero, right? It's always [set] at zero, right,= 10 15
- S1: Oh, |yeah
- TA:= |so this is 30.=
- S1: Right
- TA:= Angle of refraction, between this two directions, so it's uh 59 minus |30. 20
- S1: |30. OK. (pause)

At the beginning of the dialog, there are actually three student questions. S1's initial referential question is followed by what is probably a rephrasing or an expansion of the original question. S2's referential question partially overlaps S1's second question, making the last part unintelligible and putting the transcription of S2's utterance itself into some doubt. Because of the overlap and consequent missing speech, it is difficult to determine to which question TA1 is responding. In any case, his response is a straightforward "no" followed immediately by an explanation. In

line 5, TA1 asks a rhetorical question, then answers it, and tags on a comprehension check at the end. (This could be considered a referential question except that S1 already gave the information, “59,” in line 1.) In this first part of the explanation, TA1 twice more uses comprehension checks, in lines 7 and 10, also in the tag form “right.” Neither student responds to any of these comprehension checks, which could be taken by the ITA as their understanding what has been explained so far, or at least a willingness on their part to have the ITA continue with the explanation.

An interesting aspect of this dialog develops in line 14. After affirming S1’s confirmation request (line 13) and restating the direction of normal, TA1 makes a mistake. He realizes his mistake—angle rather than direction of incident—and corrects it, but not clearly enough. This misunderstanding becomes apparent as the dialog continues with S1’s confirmation check (line 22):

S1: So the angle of incidence is zero, right?

TA: Yeah, |yeah.

S2: |Zero!?! For all of [...]

S1: They’re all zeros?

25

TA: All zero. No no! This is angle of incident. [I meant]
direction of the incident is zero.

S1: So it’s 30.

TA: So 30, yeah.

S2: OK. So,

30

TA: (laughs) Make sure you have them down OK though.

S2: OK, so one more

TA: [It’s airconditioned, I’m so hot!]

TA1 does not correctly respond (line 23) to S1's confirmation check, perhaps because of not hearing it completely or not listening carefully enough. It is S2's expression of disbelief (line 24) and S1's consequent referential question (line 25) that cause TA1 really to look at what the students are doing and correct the mistake made earlier. This is one example of the commitment to communication that students and ITAs have in a lab setting which perhaps would not be as strong in a situation of polite conversation or even a recitation class.

TA1 is not alone in using comprehension checks; however, TA2 is more likely to use display questions when answering student questions. The following short dialog includes two display questions by TA2 as well as a clarification request, also typical of the interactions with his lab students. (TA2 side A 8:18)

S1: This is your normal, right?

TA:Sorry?

S1: Is this your normal to this?

TA:Yes, that's the normal to the surface.

S1: When they're talking about these rays, this ray entering the block, [draw] on the graph toward or away from the normal of the surface, which way are they talking about, this way or this way? 5

TA:Umm

S1: Oh this is the way. 10

TA:What is the incident beam?

S1: The incident beam [I guess] is this one.

TA:OK, [if] that beam strike this surface, and the normal to this

surface is this line,

S1: Right.

15

TA:Right? Then the question is, if there was no block, then the
beam should go straight ahead.

S1: Mhm

TA:But because of the block, does it go toward this line or away
from that line?

20

(long, thoughtful pause interrupted by the arrival of the lab
partner, late to class)

The conversation is initiated by S1 with a referential question. Instead of answering directly, TA2 asks for clarification (line 2). S1 then rephrases the question (line 3), which TA2 then answers affirmatively, repeating the key term in its full form (line 4). The student follows with another referential question containing a rather long lead. TA2, instead of providing the answer, stalls for time. S1 then answers his own question (line 10).

In general, TA2 uses display questions when students request additional information to what he has already given, as is the case in this dialog. Although S1 has already come up with an answer, TA2 asks him to display knowledge about the experiment needed for understanding the answer. Once S1 has indicated that he knows this much (line 12), TA2 continues with the explanation and ends with another display question (lines 19-20), which is essentially a rephrasing of S1's referential question in lines 7-8. Perhaps due to the late arrival of S1's lab partner diverting attention away from the problem at hand, this particular display question is never answered, putting it in the unusual position of dialog final.

General conclusions about the ITAs' use of questions can be drawn from the numbers in the tables, but clear examples are harder to find in the data than the tables indicate. The interactions between the students and their ITAs are many and varied. Some of the dialogs containing elements common to the majority of interactions (e.g., student referential questions) also have interesting twists worth examining.

An excerpt from a dialog between TA2 and two of his students contains the usual referential and display questions. Also included are expansions of questions and a student's expressive question at the end. (TA2 side B 36:16)

S2: That's a whole centimeter there.

S?: There we go.

S2: Now do we measure? The distance between 'em?

TA: You have to find the focal length.

S2: OK

5

S1: [So] the focal length's um (flips pages) Oh that should be [...]

TA: To find focal length, you have to focus the beam.

S1: Oh, OK. Then that'd be the- to the center of the- the lens?

TA: OK, what is definition of focal length?

S1: That's the point at which the light rays converge.

10

TA: OK, then, converge, what kind of rays?

S1: Parallel rays.

TA: Right.

S1: Incoming parallel rays will converge at the |focal point.|

TA: |OK then| what about diverging lens? For diverging lens, [you]-

15

what's the definition at the focal length?

S2: That's where it reaches infinity? [...]

S1: Well the focal length would be- for diverging lens- if this
were a diverging lens, the focal length would be back here,
|wouldn't it?

20

TA: Yes, that's right. But how do you find it?

S1: By bringing the in- converging, rays, and when they go out
parallel, =

S2: Yeah

S1: = at the point from convergence to the point at which they go
out parallel, that would be the focal length.

25

TA: Yes, that's right.

S1: So do I win?!

(laughter)

TA: Yeah

30

The first question in this excerpt is a referential question by S2 immediately followed by an expansion of it (line 3). It is interesting to note that TA2's response to S2's yes/no question is a statement which implies "no." As the dialog continues, it becomes apparent the students are still unsure of what they are trying to measure. In line 8, S1 asks a referential question, to which TA2 responds not with a direct answer but with a display question (line 9). When S1 gives an answer, TA2 counters with another display question (line 11) asking for more specific information. S1 gives the correct answer as affirmed by TA2 and even restates it in a complete sentence. TA2 then asks yet another display question (line 15) related to the current topic but with

a different element (diverging lens versus converging lens) and expands it to be more specific. Both students respond to this display question with referential questions, first S2 using a statement form with rising intonation (line 17) and second S1 making a statement with a tag marker at the end (lines 18-20). TA2 answers S1 affirmatively, overlapping the tag, and again asks a display question (line 21, possibly a rephrasing of line 16). S1 then makes an acceptable explanation to which TA2 again responds, "Yes, that's right," but does not follow with another display question. S1, feeling comfortable enough with TA2 and his lab partners to make a joke, expresses humor in the question "So do I win?!"

TA2 commented after the lab class was over that he did not feel his English speaking ability was good enough for joking with his students. However, from the excerpt above, we see that at least one of his students did not perceive TA2's ability in English to be a problem insofar as understanding humor was concerned. It is reasonable to believe that the students had a fair idea of what their ITA's general language level was at the time this class was observed during the thirteenth week of the semester.

A counter example of student humor from TA1's lab class, including an instance when TA1 attempts to make a joke, shows how the dialog can become a dispute when one student perceives the joke to be at his expense and sees no humor in it. (TA1 side B 36:32)

TA: You haven't learned in class?

(short pause)

S1: Uh-uh.

S2: Have we learned that in class?

- S3: Yeah, it's 1.4. 5
- S2: Yeah, OK, that's what I thought; there are two |times sine 45.|
- S1: |Yeah, that's what we thought.|
- S2: Like I said!
- (TA laughs)
- S?: No [one ...] you. 10
- S3: No I- no I'm the one who figured it out so,
- S2: I figured it out; he doesn't know what he's doin'! He really |[doesn't].
- TA:(laughing) |What's your name; I will- I will try to remember
your name so, (laugh) I can judge who is- (laugh) which [will]
get a [better] score! 15
- S3: Hey, I'm the one getting an A in this class, so |that's [why]-
- S2: |Oh, are you?
- (laughter)
- S3: Yeah.
- S2: (laughing) Yeah, yeah, you are! |Yeah, you're| not! 20
- S3: |I am!| You wanna walk out and look at it on the board right now?
I will show it to you on the way out.
- S2: (still laughing) Yeah, you're not.
- S3: How much do you wanna bet?? I swear to God I'm getting an A
in this course, so get off my back. 25

This section of the dialog starts simply with the ITA asking the group of students a referential question regarding the method of calculating the index of refraction as one over the sine of the critical angle, which supposedly was presented in their lecture

class. The responses vary from a negative by S1 to a positive by S3, with S2 restating TA1's question as a referential question again, perhaps not remembering whether he had seen it done before in class or not. There is no sign of a problem until the students start disputing who "figured it out" and S2 makes a joke to TA1 about S3 (line 12). TA1 chooses to follow with a joke which favors S2 over S3, starting with a rhetorical question (line 13), but he has difficulty completing the idea. His own laughs and false starts slow him down. In any case, the students do not show an appreciation for TA1's attempt at humor (absence of laughter), and in fact, S3 begins to get defensive (line 16). S2 continues to pick at S3, who becomes angrier, and TA1 does not enter the dialog again.

One could argue that it is not an ITA's responsibility to play referee or mediator between students. However, ITAs could be made aware of inappropriate uses of humor so as not to make or laugh at jokes which might threaten or put a student at a disadvantage or unfavorably compare students. Also, intentional verbal humor requires the right combination of content, expression, and timing. Too slow a delivery or awkward pausing can cause a joke to "fall flat." Getting the right combination is not necessarily easy for native speakers of a language much less non-native speakers. That TA2 felt inhibited about joking with his students is quite understandable. This is not to say that TA1 should not have tried; however, he might have been more successful had he kept his joke short and simple and not directed at a student.

ITAs may encounter many situations in the lab classroom besides student humor and student anger. Other possibilities include student manipulation and impatience, cheating, and disinterest. In addition, ITAs may have difficulty with the ways their students attempt to communicate with them: using informal speech, asking indirect

questions, phrasing questions poorly, not waiting for one question to be answered before asking another, or overlapping or interrupting others' speech. Interactions in the lab can be very complex.

The two ITAs observed for this study both considered their main job in the lab classroom to be answering students' questions. Consequently, when one of TA2's students asks a question about the lab early in the period, TA2 does not hesitate to give him the information. (TA2 side A 12:28)

S1: Can you explain why it's doing this? The ray entering the
block, refracts, away from the normal to the surface.

TA:What is your question?

S1: I s- we see why it does that but why- I mean we see that it
does that, but why does it do that? 5

TA:Why- why does it bend toward the normal?

S1: Yeah.

TA:Uh, that's because of the difference of index of refraction=

S1: OK

TA:= between air and, 10

S1: Is that the same thing for why this does that away from it?

TA:Yes, that's the same reason but, depending on from where to
where the beam goes, there's a change in angle,=

S1: OK

TA:= direction of the angle. 15

(S1 writes the response down as the answer to a question on the lab
report.)

S1: All right.

TA: So to bend toward the normal to the surface, does the index of
refraction should be greater than one, or smaller than one? 20
(pause)

S1: What'd you say?

TA: To bend toward the normal to the surface, um, is the index of
refraction of this plastic |should-|

S1: |Is greater, isn't it? 25

TA: Greater than one? Should it greater than one?

S1: Is that right or not? (clatter from object dropped on
neighboring table) Huh?

TA: Yes, that's right.

S1: OK 30

In this dialog, S1 seems to use TA2 to get the information he needs to fill in the blank on his lab report. When TA2 asks a display question (lines 19-20) to check S1's understanding of the previous subject matter, he is met initially with silence. S1 does respond eventually with a clarification request (line 22) but then interrupts TA2's rephrasing (lines 23-24, not counted) of the question with a guess at the answer in the form of a tag question (line 25). TA2 makes a confirmation check and repeats it (line 26) with a slight rephrasing by including a verb and subject. S1 responds this time with the referential question "Is that right or not?" which hints at impatience.

From TA2's nonverbal reaction at the time (unfortunately, there was no video camera present to record it) and from his comments after the lab, he felt he had been manipulated and was angry. How should an ITA react when he perceives that a

student is asking questions simply to fill in the required lab report blanks and is not interested in answering the ITA's questions? In this case, TA2 responded affirmatively and unemotionally to S1's referential question in line 27 and then moved on.

This kind of situation where it seems that the ITA is DOING the work for the student rather than HELPING the student understand the work might be a worthwhile topic of discussion between ITAs and advisors or other supporting faculty. Where does one draw the line between doing for and helping with, and how?

Another situation which lab ITAs might encounter is that of student cheating. Consider the following dialog in which TA2 sees a completed graph on the lab table of two students who apparently have not yet finished the corresponding portion of the lab. (TA2 side A 43:31)

TA: Did you draw this graph? (picks it up)

S1: No.

S2: Uh-uh. Nope.

S1,S2:(simultaneously) Why, is that right? (laugh)

S2: What did it get?

5

TA: You have to do your own.

S2: Well, it must have been good!

(laugh)

Here TA2 initially asks the two students a question which has been classified as referential because the ITA did not know absolutely the answer, although he probably had a strong suspicion and wanted verification. It is interesting to note that TA2 did not answer either of the two student referential questions, but rather instructed S1 and S2 to do their own work. Perhaps the students did not really expect answers

but were reacting with humor to being caught, in which case their questions might be more appropriately classified as expressive or humorous rhetorical. Anyway, as the laughter indicates, the students were good-natured about the situation, and TA2 was able to be firm and also good-natured. (He kept the graph.)

Not only might ITAs in lower-level labs have to deal with students who manipulate or use other students' work in order to finish the lab as soon as possible, but they also will probably find more than one disinterested student who wants only to LEAVE the lab as soon as possible, finished or not. The wish of the student to be elsewhere is perhaps stronger on a Friday afternoon than at any other time during the week, particularly on a nice spring day. In the dialog below, TA1 uses questions to coax two students into staying and doing more work on the experiment. (TA1 side B 12:39)

TA:[? do the whole part.]

S1: Aw, do we have to do it?

TA:Yeah.

S1: Why?

TA:Yeah.

5

S1: We have to go.

TA:You have to go? It's, (S1 laughs, kind of) a two hours lab

(laughing) you see;=

S1: |Two hours!|

TA:= |there are| forty minutes left. |You should try.|

10

S1: Well, this |is punishment because we got done early.|

S2: |Nobody else is doing- nobody else has got|ten this far.

TA:No. There's uh several groups last semester they can. Yeah
 but, all those people [...] they try to finish so they, stay until
 finish. 15

(S1 sighs)

TA:It's very interesting. If you- if you (S1 laughs) [...] just
 see that. [...] set [it] up and see what happen. OK?
 (pause)

S2: But- I mean, it was the same thing that was on the slide show. 20
 (laughter)

TA:[Cannot] see the slide show. That's by yourself you see
 (laughing). Just like you see a lot of- you s- watch a lot of
 movies, but you can never be actor, right? Now you're actor,
 not watching movie, totally different! 25

S2: Well can we do it without writing stuff down? Can we just-

S1: I mean do we-

TA:Hmm.

S1: |[...]|

TA:|Yeah,| try your best. I hope you can write this whole thing 30
 down (laughing) start and finish all part.

S2: OK. But that means we have to be here till six.

TA:Mhm.

(pause)

Although the initial statement by TA1 is partially inaudible, S1's subsequent
 appeal (line 2) not to have to do the rest of the lab is completely clear. When

told by TA1 "Yeah" they have to do all of it, S1 then responds with the disputatious query "Why?" For whatever reason, TA1 answers with a grammatically inappropriate repetition of his previous response, "yeah," which has the same effect as the common no-answer response "because." It leads the student to a dead end. S1 then tries a new tactic (line 6) for getting out of lab early, which leads TA1 to make a confirmation check (line 7) with a note of surprise in it. The remainder of the dialog consists of the two students trying to persuade TA1 that they should not have to finish the rest of the lab while TA1 tries to convince them that it is worth their while to stay and complete as much of the lab as possible. In line 18, TA1 uses the tag "OK" as a directive with the impression of an appeal. He uses a tag again (line 24) in a rhetorical question in an effort to convince the students that it is to their advantage to do the rest of the lab. S2, while giving way, makes one more appeal (line 26) to shorten the process and thus the necessary time to finish the lab, but TA1 holds firm.

The ITA in the laboratory may encounter not only many different student attitudes and behaviors, but also a wide variety of verbal communication techniques. Not all techniques are helpful. Some that may cause difficulty for the ITA are informal speech, interruptions or overlapping of speech, multiple-question utterances, indirect questions, and simply poorly phrased questions.

Part of informal speech is the use of idioms. For some reason, many idiomatic expressions in American English are taken from sports, especially baseball. Such is the case with the following example from TA2's lab, in which a student initiates a dialog with the question: "[Are we] in the ballpark here?" (TA2 side A 44:27)

Phrasal verbs, which are verbs followed by one or more preposition usually necessary to give the verbs their new meaning, are also very common in informal speech.

They might cause some problems for ITAs more familiar with textbook English. The excerpt below is an example of a student initiating a dialog with a referential question including the phrasal verb “match up with.” (The dialog takes place during a pause in the middle of another dialog.) (TA2 side B 18:31)

S3: Is the focal length supposed to match up with the number [on]
the lens?

TA: Match?

S3: Is it supposed to be the same? If it's a five centimeters, is
it supposed to be five centimeters apart?

5

TA: Yes.

S3: OK.

Fortunately, when TA2 shows by his clarification request that he is unfamiliar with the verb, S3 is easily able to rephrase the question, first in a general sense and then specifically with an example.

Use of words figuratively might also be troublesome for ITAs with a lower level of English. (TA1 side B 24:03)

S1: This is pretty fun, isn't it!

TA: You think so? (laughs) I saw you're waiting here.

(pause)

S2: [Well] we're stuck right here.

TA: Stuck, uh-huh.

5

S1: Oh. You just use Snell's Law.

In this example, TA1 provides an invitation (line 2) for the students to ask for

help, which after a pause, S2 does, indicating where they are having problems. He uses the word “stuck” figuratively, which TA1 repeats and follows with “uh-huh.” Whether this is an indication that TA1 understands or not is unknown as he does not immediately start to explain to the students nor does he ask for clarification before S1 proposes a solution.

Another common occurrence in informal speech is interrupting or overlapping. Compared to a recitation class, a lab class offers a good atmosphere for several people to talk at once. This can be rather confusing, although not necessarily impossible for comprehension. TA1 and two of his students managed to carry on a conversation in spite of multiple interruptions and overlaps in the following excerpt. (TA1 side B 18:05)

S1: ...But the fact that these are almost 1.5 and these are just
about 1.4, is there, like [difference]? Is that— isn't it—

TA: That's error. Because this is experiment |and not—| yeah.

|I(t)— it's—| yeah, that's no problem.

S2: |Oh it's just— oh, OK. Well that's no problem then. We can| 5
handle |that.|

S1: |All right. [...]|

TA: |You| cannot get exactly, because theoretical is exact but it—
if you're doing experiment, =

S2: Uh-huh 10

TA: = it's machine and |then you got human errors, so,| yeah.

S2: |Oh, OK. So it—| OK.

All three interrupt and overlap each others' speech, but they do it in such a way

that in this case only two of the three are actually talking at the same time (e.g., while TA1 is saying "and not-", S2 is saying "Oh it's just," and S1 is momentarily silent).

In another conversation, two students respond to a display question asked by TA2. From his response, one cannot determine whether only one or both students were heard and answered. (TA2 side B 43:41)

TA: What is angle of refraction?

S1: |It's from the normal, right?|

S2: |Angle of refraction?|

TA: Yes.

TA2's "yes" is an equally appropriate response to S1's referential question and to S2's confirmation check. Later in the same dialog, TA2 and two of the three students again overlap.

TA: That sounds right, but I don't |know how you get it.|

S1: |Heh-heh-heh!| I do.

TA: By the way, |why is that| the |angle| of refraction?

S3: |How do you get it?|

S1: |We took-| the angle of refraction would be 90 degrees, = 5

TA: Right.

S3: |Oh that's right.|

S1: = |and the angle-| and the other angle's what 45 degrees, so
you take 90 by 45 and, you get one-oh- one point four.

Having received the correct answer to his previous question ("What is angle of

refraction?"), TA2 indicates that it seems right, but he does not understand S1's method of obtaining it. S1 does not consider TA2's statement to be an indirect question and does not explain the steps of solving the problem until after TA2 asks the display question (line 3) requesting an explanation of why S1's answer is the angle of refraction. Meanwhile, S3 asks the question "How do you get it?" probably as a referential question to S1 but possibly as a confirmation check to TA2's statement in line 1. More overlaps occur as S1 makes his explanation, first interrupting TA2's question and then being interrupted by S3's comment (line 7).

There has been some discussion that multiple questions made by teachers in the classroom in an attempt to clarify the first question in an utterance may actually oversimplify the original question or confuse the students as to what they are expected to answer (Bonnstetter, 1988, and Andrews, 1980). Whether they clarify or confuse, a barrage of questions can be expected by the lab ITA from students whose wait time is not as long as the time needed for the ITA to form a response. The sample below is a three-question utterance initiating a conversation between a student and TA2. (TA2 side B 1:03)

S1: Can you help us, does this need to be out here? We have to
take this out, don't we.

TA: You have to take it out.

S2: That's what we wanted to know....

S1's first question is a directive in a simple yes/no form. His second is a referential question also in a simple yes/no form. The third question rephrases the second using a tag form. TA2 answers the third question.

Indirect questions come in the form of a statement, with or without a WH

question marker (e.g., what, why) and expecting an answer to follow as in other question-answer adjacency pairs. Because indirect questions—whether declarative (with a Q-marker) or hidden (without a Q-marker)—have the grammatical form and intonation of a statement, they may be difficult for ITAs to recognize. However, students commonly use them to request information, so a look at some typical indirect questions might be helpful.

A good indication that a student is asking an indirect question is when he or she begins a statement with the words “I/we don’t understand...” or “I/we don’t know...” often followed by a Q-marker such as “what.” The following excerpt from TA1’s class is initiated by S1 with a referential declarative question. (TA1 side B 19:38)

S1: We don’t understand why there’s no relation. I mean, you said
there was no relation between theta one and theta two? (short
pause) Didn’t you tell me that?

TA: Yeah, there’s no relation between theta one and theta two.

S1: But why— I mean, it says,— it says explain why— I don’t
understand why it’s not. 5

Instead of forming a simple WH question such as “Why is there no relation?”, S1 chooses to start with the indirect question indicator “We don’t understand” and follow it with the uninverted form of the previous WH question “...why there’s no relation.” With the next question, he is simultaneously asking for clarification of a statement made by TA1 prior to this conversation and rephrasing the declarative question by expanding it (counted as clarification). After a short pause, he asks for verification. TA1 verifies the statement that there is no relation between theta one

and theta two, but he does not continue with an explanation of why. Consequently, after a few false starts, S1 repeats the declarative question, slightly rephrased.

In TA2's class, a student uses the similar indirect question indicator "I don't know" to request clarification of TA2's previous statement. (TA2 side B 2:10)

TA: Yeah. Anyway, what you have to do is make parallel light. And then, the parallel light should come through this lens, and then they have to focus. Then that's focal length. If they're well focused. But this is not parallel light, so you have to make it parallel.

5

S1: Parallel. I don't- I don't know, what, you mean.

(pause)

In this case, the declarative question "I don't know what you mean" goes unanswered for quite some time, but TA2 realizes that a more extensive explanation of focal length, including the necessity of parallel light entering the lens, is required. Eventually the students understand.

Although the key terms "don't understand" and "don't know" are good indicators of indirect questions, they are not the only ones. Sometimes an indirect question has neither a key term such as those above nor an embedded question marker to indicate that information is requested. In the short dialog below, the best clue that a hidden question is being asked may be that the statement made by the student initiates the conversation. (TA2 side B 21:03)

S1: We reverse these, and then we should get the right index of refraction.

TA:Yes.

S1: OK.

This type of hidden question gives the impression that S1 is really looking for reassurance that he knows what he is doing rather than for unknown information. However, had S1 not been correct in his statement to which TA2 would have then responded "no," TA2 would have been expected to supply the correct idea and possibly an explanation for why one is right and the other wrong.

While indirect, especially hidden, questions may be a problem for ITAs because of their misleading form and intonation, other questions may be difficult to answer because they are poorly phrased. (TA1 side B 20:33)

S1: Hey um, we measure pretty much from the middle, right?

TA:Mhm. From middle, yeah. (pause) What's this? Minus 20.

(pause)

S1: So do I wanna like, figure out how much- how- the spacing

between here and [then], the spacing now? Or something? 5

TA:How you got it this way? You just [add? have?] this on focal,
right?

(pause)

The question initiating the dialog is pretty straightforward; however, S1's second utterance is a little more complicated. The language is informal (as was the first question), there are a couple of false starts, the wording is somewhat confusing, and the whole question takes the form of an open-ended "specified" alternative because of the final addition of "Or something?"

Instead of answering S1's question, TA1 asks a rhetorical question regarding the way the equipment is set up to produce the current results in question. He then follows immediately with the answer in the form of a comprehension check. After the pause, S1 asks for clarification, which leads TA1 and both students at the table into a long explanation of what it is they are trying to do with this part of the experiment.

A question may be poorly phrased if it initiates a dialog without a frame of reference to provide the context. In the following excerpt from TA2's lab, a student asks a general referential question in the form of a WH-embedded yes/no and then makes a statement about the problem which provides a context for the question already asked. (TA2 side A 12:28)

S1: Can you explain why it's doing this? The ray entering the
block, refracts, away from the normal to the surface.

TA: What is your question?

S1: I s- we see why it does that but why- I mean we see that it
does that, but why does it do that?

5

TA: Why- why does it bend toward the normal?

S1: Yeah.

TA2, for whatever reason, is unsure of what S1 is asking, so he asks for clarification (line 3). Unfortunately, S1's rephrasing (lines 4-5) of the original question is perhaps even more difficult to comprehend with its false starts. TA2 then has to make a confirmation check (line 6), which is affirmed by S1, before being able to answer the question. Once TA2 has given the answer, S1 again asks a rather nonspecific question sounding suspiciously like his first two: Is that the same thing for why this

does that away from it? Perhaps there was some confusion on his part between the light ray bending TOWARD and bending AWAY from the normal to the surface.

A question form that sometimes causes difficulty in communication is the specified alternative (or-choice) form. This type of question is composed of two or more yes/no questions joined by "or," forcing the respondent to give specific information, whether one of the choices in the question or a completely different piece of information. Confusion results if the respondent, perhaps hearing only one part of the question, answers it as a yes/no. The excerpt below is an example of this situation. (TA2 side B 9:51)

S1: So we gotta make, (tap, tap, tap) all these thetas into Ys or
sine theta into Y?

TA:Yes.

S1: Sine theta?

Here, TA2 makes an inappropriate response, "yes," to S1's specified alternative, referential question. S1 then must ask for clarification, choosing to repeat the second alternative.

Another common question form which might be difficult for non-native speakers is the combination open-closed, which contains a WH question and either a yes/no or specified alternative. Consequently, the response could take a variety of forms. The excerpts below, taken from TA1's class, contain a combination of WH questions and elliptical yes/no suggestions. (TA1 side B 5:28) (S1's question concerns the approximate orientation of the flat side of a plexiglass semi-circle, with respect to the critical angle of the light ray.)

S1: So what's that about, 135 and, 315?

TA:Mhm. Yeah....

(TA1 side A 9:05)

S1: ...how long does this lab take, about an hour? Longer?

TA:Longer than two hours.

In the first example, the student's suggested answer (the elliptical yes/no part: (Is that about) 135 and 315?) is correct, and TA1 is able to respond appropriately with "Mhm. Yeah." However, the student's question in the second example is more complicated to answer not only because the suggested response is incorrect but also because it is expanded, much like a specified alternative, with the addition of "Longer?" In this case, TA1 answers the first, or WH, part of the question, which could have been more easily put forth as just "How long does this lab take?"

Another example of a combination question, from TA2's lab, has the form of an elliptical specified alternative in the second part. (TA2 side A 8:18) (on the incident beam refracting toward or away from the normal to the surface)

S1: ...which way are they talking about, this way or this way?

TA:Umm

S1: Oh this is the way.

Before TA2 chooses an answer, S1 decides one for himself. Had S1 not stated his own answer, TA2 could have responded either to the elliptical specified alternative by choosing one of the suggestions or, if both choices were incorrect, to the WH part of the question by stating the correct direction.

These combination questions need not be long and complicated. (TA2 side B 46:06)

TA:...Then the refracted light will disappear. To do that, you have to rotate this, and then look at this point. (pause) It disappear around here. Right?

S1: Where, here?

TA:Here.

5

S1's clarification request is a very short combination of an elliptical WH and yes/no.

TA2 also uses this combination question form, but in the following example he inverses the order, putting the specified alternative first and the WH question last. (TA2 side B 30:20)

TA:The index of refraction should be greater than one or smaller than one, what do you think?

Besides question forms, there are other aspects of spoken English worth noting, two of which can be found in the following excerpt from TA2's class. One is the expectation of an explanation following a "no" answer, and the other is the importance of word stress to the meaning of sentences. (TA2 side B 2:10)

S1: ...Now I wanna know focal length of the lens. Focal length would be [as far as this is], isn't it? Isn't that the focal length?

TA: No.

S1: What IS the focal length? 5

TA: What is the FOCAL LENGTH?

S1: Right.

TA: Uh, what do you mean by THIS is the focal length? That's that lens. Only lens have focal length.

S1: All right. So it must be the difference between these two. 10

TA: Yeah....

In the first utterance of this excerpt, S1 makes a statement regarding the new focus of the experiment. He follows immediately with a referential question and a rephrasing of the question with practically no wait time in between. When TA2 responds to his multiple question utterance simply with a "no," S1 indicates by emphasizing the verb "is" in the question "What is the focal length?" that he expects the correct information to be given. TA2 responds not with the answer to S1's question but with an exact repetition, the only difference being the word emphasized. By placing the emphasis on "focal length," he confirms that he has correctly heard what S1 is asking about. TA2 then asks a rhetorical question and gives information that leads the student to the answer he has been seeking.

CHAPTER 5. DISCUSSION AND CONCLUSIONS

The main function of questions in the two physics labs in this research project is apparently to keep communication going, as well as to obtain information (especially on the students' part). The ITAs and their students used a wide variety of question forms to meet these needs and others.

The lab setting, unlike a recitation or lecture class, is conducive to question asking. First of all, the lab experiments themselves are investigative in nature, and students working alone or with someone else who is confused need not feel self-conscious about asking questions. In a recitation class or large lecture class, however, a student might very well withhold questions to avoid looking like the only one who does not understand. The one-on-one interaction in lab classes also allows extensive negotiation of meaning to answer one student's question without forcing others who do understand to sit idly by. It should be noted that the lab situation, in which students asking questions know exactly what the context is but the TAs have only a general idea of the possibilities, almost necessitates negotiation of meaning. Students sometimes initiate a dialog with a question like "Are these the right numbers?" If the TA is going to be able to answer appropriately, some clarification is needed.

Implications

At Iowa State University, the English department has a class (180) for ITAs who want and need to improve their teaching and spoken English skills. The class includes instruction on questioning techniques, but the emphasis is on explaining material as in a recitation class or the TEACH test. Since the ITAs required to take the course are typically placed as lab assistants, perhaps the focus should be on teaching as in a lab setting, with the emphasis on questions, appropriate responses, and negotiation of meaning.

One of the unwritten assumptions on the TEACH ratings is that a higher level of English is needed to teach a recitation section than a lab section. After observing several different labs and analyzing the discourse of two, I realize how difficult teaching a lab can be. Although there is a better opportunity for repairing misunderstanding than in a recitation, comprehension is more difficult to come by in a lab in the first place. The context in which students initially ask questions is not shared by the ITA and in fact changes from student to student depending on their rate of working through the experiments. Labs are quite often noisy places: people talk, chairs scrape, equipment falls, machines run, etc. Even when asking the ITA for help, students working together will sometimes talk simultaneously or interrupt each other and/or the ITA. Questions also may have false starts, poor wording or phrasing, self-interruptions, or any number of problems that make them difficult for the ITA to understand. The lab ITA in effect is given an often poorly formed question on a topic of the student's choosing in a noisy environment, and he or she must negotiate the context and meaning before responding appropriately—on the spot! This is not what I would call an easy task even in my native language. More practice in the 180

class in answering questions of this sort could be very useful.

The 180 course, along with giving ITAs an opportunity to answer questions as if in a lab setting, could also give ITAs more instruction and practice in asking rhetorical and display questions as a teaching technique. Besides being useful in assessing a student's understanding, display questions can help students learn by leading them to an answer and exploring the underlying concepts in the process. Rhetorical questions can also help students learn by focusing their attention on important information and causing them to think beyond the step-by-step procedures of the lab experiment.

Limitations

As was mentioned earlier, there were some difficulties in gathering the data for this project. Although the hand held tape recorder made the collection of data infinitely easier and more reliable than just attempting to take field notes, it still posed problems. Noises which interfered with hearing the discourse at the time of observation were just as loud and obstructive to understanding on the recordings. Also, some dialog was lost completely simply because I could not unobtrusively get close enough to the speakers, who were often bent over the problem at hand or speaking quietly, in which case a microphone attached to the clothing of the ITA would have been helpful. Another problem with the tape recorder was that the tapes ran out before the class time did and had to be turned over, thus possibly omitting a portion of speech. As a result of these difficulties and others, the data collected for this study are not complete and can only be used as an indication of questioning trends in introductory physics labs.

Another limitation of this research is its scope. More data taken from lab sessions

in several different fields at both beginning and advanced levels and at various times throughout the semester would yield a more complete view of the role of questions in lab classes. There is obviously plenty of room for future research here.

Future Research

Some future research possibilities are a) an evaluation of the results of ITAs' teaching skills in lab classes after having focused on questioning techniques in English 180, b) a more extensive study in some of the other science or engineering fields regarding the use of questions in lab classes, or c) a comparison of question functions between beginning and advanced level lab classes in the same field. The effect of training students in how to ask questions in the lab setting would also be interesting.

BIBLIOGRAPHY

- Andrews, John D. W. 1980. The verbal structure of teacher questions: Its impact on class discussion. POD Quarterly 2 (3-4):129-163.
- Bailey, Kathleen M., Frank Pialoski, and Jean Zukowski-Faust (Eds.). 1984. Foreign teaching assistants in U.S. universities. Washington, D.C.: National Association for Foreign Student Affairs.
- Bloom, Benjamin S. 1956. Taxonomy of educational objectives. New York: Longmans, Green.
- Bolinger, Dwight L. 1957. Interrogative structures in American English. (Publication 28 of the American Dialect Society). University, Alabama: University of Alabama Press.
- Bonnstetter, Ronald J. 1988. Active learning often starts with a question. Journal of College Science Teaching 18 (2):95-97.
- Bozack, Michael J. 1983. Tips for TA's: The role of the physics teaching assistant. The Physics Teacher 21 (1):21-28.
- Byrd, Patricia, Janet C. Constantinides, and Martha C. Pennington. 1989. The foreign teaching assistant's manual. New York: Collier Macmillan.
- Celce-Murcia, Marianne, and Diane Larsen-Freeman. 1983. The grammar book: An ESL/EFL teacher's course. Rowley, MA: Newbury House.
- Churchill, Lindsey. 1978. Questioning strategies in sociolinguistics. Rowley, Mass.: Newbury House.
- Gaies, Stephen J. 1982. Native speaker-nonnative speaker interaction among academic peers. Studies in Second Language Acquisition 5 (1):74-81.

- Goffman, Erving. 1976. Replies and responses. Language in Society 5 (3):257-313.
- Goodwin, Stephanie S., Gregory W. Sharp, Edward F. Cloutier, and Nancy A. Diamond. Effective classroom questioning. Office of Instructional and Management Services, University of Illinois at Urbana-Champaign.
- Johnstone, Alex H. and Kirsty M. Letton. 1988/89. Is practical work practicable? Journal of College Science Teaching 18 (3):190-192.
- Kandel, Marjorie. 1989. Grading to motivate desired student performance in a descriptive laboratory course. Journal of College Science Teaching 18 (4):249-251.
- Kearsley, Greg P. 1976. Questions and question asking in verbal discourse: A cross-disciplinary review. Journal of Psycholinguistic Research 5 (4):355-375.
- Koser, John F. 1988. High-energy lab activities. The Science Teacher 55 (9):38-41.
- Kyle, William C., Jr., John E. Penick, and James A. Shymansky. 1980. Assessing and analyzing behavior strategies of instructors in college science laboratories. Journal of Research in Science Teaching 17 (2):131-137.
- Long, Michael H. 1982. Questions in foreigner talk discourse. Language Learning 31 (1):135-157.
- Long, Michael H. 1983. Linguistic and conversational adjustments to non-native speakers. Studies in Second Language Acquisition 5 (2):177-193.
- Long, Michael H. and Charlene J. Sato. 1983. Classroom foreigner talk discourse: Forms and functions of teachers' questions. In Herbert W. Seliger and Michael H. Long (Eds.), Classroom oriented research in second language acquisition. Rowley, MA: Newbury House. 268-285.
- Luthy, Melvin J. 1983. Nonnative speakers' perceptions of English "nonlexical" intonation signals. Language Learning 33 (1):19-36.
- Merriam, Robert W. 1988. A function in trouble: Undergraduate science teaching in research universities. Journal of College Science Teaching 18 (2):102-106.
- Merritt, Marilyn. 1976. On questions following questions in service encounters. Language in Society 5 (3):315-357.

- Miles, Matthew B., and A. Michael Huberman. 1984. Qualitative data analysis: A sourcebook of new methods. Beverly Hills: Sage Publications.
- Myers, C. and Barbara S. Plakans. 1990. The discourse community of the university scientific laboratory. Paper presented at TESOL '90, San Francisco, CA.
- Myers, C. and Barbara S. Plakans. 1991. Under controlled conditions: The ITA as laboratory assistant. In J. Nyquist, R. Abbott, D. Wulff, and J. Sprague (Eds.), Preparing the professoriate of tomorrow to teach: Selected readings in TA training. Dubuque, IA: Kendall/Hunt
- Myers, C. 1991. Question based discourse in science labs: Issues for ITAs. Manuscript submitted for publication.
- Orear, Jay. 1979. Teaching a large physics class at Cornell. The Physics Teacher 17 (8):519-521.
- Paldy, Lester G. 1988. Ends and beginnings. Journal of College Science Teaching 18 (1):7,66.
- Pestel, Beverly C. 1988. Some practical distinctions between preaching, teaching, and training. Journal of College Science Teaching 18 (1):26-31.
- Pickering, Miles. 1983. Should teaching assistants be asked to play the role of Socrates? The Chronicle of Higher Education.
- Plakans, Barbara S. 1987. Comprehension problems of teaching assistants who are nonnative speakers of English: How U.S. students ask them questions and why they may have difficulty answering. Masters thesis, Iowa State University, Ames, Iowa.
- Rounds, Patricia L. 1987. Characterizing successful classroom discourse for NNS teaching assistant training. TESOL Quarterly 21 (4):643-671.
- Stubbs, Michael. 1983. Discourse analysis. Chicago: University of Chicago Press.
- Sutton, Richard M. 1974. On asking (and answering) questions. In Teaching introductory physics: Reprints from The Physics Teacher, Apr. 1963-Dec. 1973. (Original publication Nov. 1963) Stony Brook, NY: Drawer AW 345-347.
- van Lier, Leo. 1988. The classroom and the language learner. New York: Longman Inc.

Varonis, Evangeline Marlos and Susan Gass. 1982. The comprehensibility of non-native speech. Studies in Second Language Acquisition 4 (2):114-136.

Varonis, Evangeline Marlos and Susan Gass. 1985. Miscommunication in native/nonnative conversation. Language in Society 14 (2):327-343.

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APPENDIX A.

Transcript Notation

The data in this appendix have been transcribed using the following conventions:

"5:52" — Each dialog is preceded by the time at which it begins relative to the starting of the tape recorder (approximately ten minutes after the start of the class for side A) and is indicated in minutes and seconds. The time 5:52 signifies that the dialog started five minutes and fifty-two seconds into the tape.

"TA:" — The following speech is that of the international teaching assistant in charge of that particular class.

"S1:" — The following speech is that of the first student to speak in that particular dialog. S2 stands for the second student to speak in the same dialog, and so forth. Once a new dialog is initiated, new students become S1, S2, S3, based on order of appearance in the dialog.

"JS:" — The observer was drawn into the dialog.

"[" — The speech contained within square brackets is questionable or unclear. When there is no way of guessing what words are being spoken, the square brackets contain an ellipsis, [...].

"()" — Parentheses contain information about or affecting the dialog other than actual speech.

" ," — Commas indicate a short pause in speech.

“.” — Periods indicate the end of a thought, determined by intonation.

“?” — Question marks indicate a query, determined by question structure and/or intonation.

“=” — Equals signs indicate that a person's speech is continued. For example, TA1 is explaining to a student “...through diverging lens and going this way and this way...” and the student inserts “Uh-huh” to indicate that she is following his explanation. In the transcripts this is written separately using equals signs:

TA: ...through diverging lens=

S2: Uh-huh

TA: = and going this way and this way....

“|” — Vertical lines, in pairs, indicate that the speech between the lines is overlapping another person's speech.

“—” — Dashes indicate interruptions of speech, whether by the same speaker (as occurs with false starts) or by another speaker.

TA1 Transcripts

Name of Class: Physics 111L

Date of Observation: Friday, 21 April 1989.

Tape: TA1 Side A

0:45 S1: um [three times something is that five]

S2: Is that five or is that zero or

TA:Uh it's not five; it's a "s." There's three kind.

One is unsatisfied, and satisfactory and outstanding,
sometimes "o" means outstanding.

S?: [...]

TA:Yeah, [there's? so only?] three kind.

3:05 S1: We didn't hand in our prelab with that.

TA:[...]

S2: Oh. [No I didn't ...] I thought you- I thought you
weren't going to accept it.

TA:No, you should finish. I just accept you hand in
right now.

S2: OK. I'm sorry.

3:37 TA: You- you didn't have this [...]?

S1: Just [2D].

TA: Yeah, you just use this one [2C]. =

S1: Yeah

TA: = [It's to rise ... times ...]

S2: Raise it up?

TA: Yeah. Then you check two place, not just one. Check
here and check there. If the position, the height,
[is] the same, then [it's ...]. Otherwise [I would
just use this]

S2: OK

TA: [...], OK. Oh, one more people coming!

4:27 S1: we use two different things rather than resetting the
whole thing up?

TA:[You] just use this one.

S2: You want us to reset this then?

TA:Yah-

S2: I mean, reset this one so it's,
 S1: [good? gonna?]
 TA: Yeah. [Just put- it should just take short time,
 you can reset here].
 S2: OK. Sounds good to me.

4:44 TA: So have you finished the prelab?
 S1: Mhm. Have to get it out.
 (pause)
 S1: [It's not perfectly done.]
 TA: What's this? [Today] it's- today is number th-
 [...].
 S1: Number what?
 TA: Number ten. OK.
 (short pause)
 S1: I'm so mad. I did not even bring the right lab.
 TA: You don't have lab report also?
 S1: I don't have any of it, 'cause I thought it was nine
 today. (short pause) (laugh) And I ran all the way
 here! Oh! (short pause) Can I do it on paper? And
 bring the prelab in on- on next Friday or put it in
 your box?
 TA: Yeah, you may record all the- all the data down, and
 you write on |[this]|
 S1: |Gosh,| I'm so sorry about that; I'm such a nerd.
 pause, walking away) I didn't even know that it was,
 god! I'm so mad, I'm so mad.

5:50 TA: [Have you turned this down already?]
 S1: No
 TA: No? [...]
 S1: What'd you say? Set-
 TA: Set- set this on level. [... these things on level.
 Turn it] up or down,=
 S1: Oh
 TA: = so you should use this one, [then] you can use this
 one.
 S1: OK
 TA: And if this one- yeah, like this one incoming here
 [...] on the outside out at 180. Yeah, it- it's

almost,same.

S1: [I'm getting ... reading]

TA: Yeah, it's [...]. Then recheck inside, yeah. Half [...] half centimeters, right. In the same place, it- it's a still half centimeters? No, you see. It's much higher.=

S1: [...] right [[...]

TA: [So that means this one, not on level.

S1: Right. [We messed up [all our level]

TA: [...] bring this [up] a little bit up [...]. Otherwise that affect your measurement in the following [unit]. OK?

S2: [How many ...?]

S1: [... enough]

S2: How do we- how do you raise these? D'you turn this, or,

TA: Yeah, you turn this first. [...] Then you use this one to check.

S1: Where is it back here?

TA: Mhm. First- yeah, first check here, it's ha- yeah, it's half centimeter, that's right, so [...] here.

S1: Incredible!

(laughter)

S1: [...] look at that. All right!

7:29 S1: Do you look at the darker one or the lighter one?

TA: Yeah, you- you look here. This is the reflected [one], this is the reflected one. So you check the- this [instrument] check- [you see]. So this incident. [Right], incident [...].=

S1: Uh-huh

TA:= [...] check this [way? ray? and it's ...]

S2: So is there one over here?

TA: Yeah

S2: |Yeah. [...] so this is reflected and this is refracted.

TA: Yeah. Then you use the- use this way. Because two point can decide one straight line, right? So you first use this one, draw your point- draw your point down there; and you change your place, get another point; then you connect this two point.=

S1: |Ohh

TA:|And use this straight line. You see the way you get, one point here and another point here, then connect this two point. So this the incident ray and reflect ray, and refract ray, so, [like that]. Then join your, [...], OK. OK.

8:33 TA: So you need more help |[with that]

S1: |Can I see your lab [for a minute?]

S2: Mhm

TA: [Need a little] more help here.

S1: Gosh, I'm so upset.

S2: She's [gonna] read mine. It's gonna take us a while to get off and running, 'cause (short laugh, pause) [Anyway] should tape this [stuff ...] paper down?

TA: There's tape over there.

9:05 S1: Hi, um, I'm a little bit late. I had to get caught up in- I got caught up in a chemistry lab that, I was making up.

TA:Have you finished prelab?

S1: Um, I don't think I've got it, no. Um, let me look it over real quick.

(long pause while S1 searches through papers)

S1: Um, no I don't, um, I can sit down and work- how long does this lab take, about an hour? longer?

TA:Longer than two hours.

S1: Longer than two hours?

TA:Yeah. Only maybe about one out of ten students can finish all. One.

S2: Oh, so we're not even expected to finish?

TA:(laughing) I expect you to finish!

(S1 laughs)

TA:But I tell you that only one out of ten students can finish that.

S2: Oh.

(pause)

TA:This is the last lab of this week. Because they will change all [this stuffs, obviously].

S1: |Right. So I don't,

TA:How many labs have you missed?

S1: Two.

TA:Two. You cannot move- miss any |more|

S1: |No,| I can't. (pause) I'd be willing to stay a little
extra; I realize I'm twenty- twenty minutes late,
|so|

TA:|OK,| you may just join them and uh finish the prelab
later and |hand| in. OK.

S1: |OK. Well- I- this won't take me very long, I don't
think.

TA:No, I don't think so, it's just so many questions, |so
[...]|

S1: |Yeah, it should just take a minute.

TA:You- you can- you can hand me later. I'll- you
[may] finish after lab.

S1: OK.

TA:? finish all this

S1: OK

11:26 S1: Do we both have to do one of these, or can we just
hook 'em together? |I mean-

TA:|You- you should do your individually.

S1: OK

(pause)

S2: But it says- well, it kind of says that it can-
attach to one of the other. (pause) [...]

TA:Yeah, OK.

S1: So just one person then?

(no audible response)

12:01 S1: First question: (pause) [... small ...]

TA:[...] use this small area of the block. This one.

S1: |[...] thick [...] thick. Right that- that's
approximately-

TA:|Yeah, yeah. Yeah=

S1: It's one centimeter approximately.

TA:= [one? half?] centimeter. Then from here, yeah,
it's unlevel. So, you [can?] do it right. Put this
one here, about the forty-fiveth degrees, then check

the- this refract one?

S1: Mm

TA: The refract one, right? Over here. And then you join the point, how to decide the incident ray, you just- one point here - [Can I] see your pencil?

S1: Mhm

TA: Your pencil? Yeah, OK. Then join one point down there, all right? Then change place and draw another point here. Since this's strai- straight line, right? So two point get this [obvious] straight.=

S1: Yeah.

TA: So, OK this two points and uh this refracted one all right? [Find a] one here, another one here, then connect this two point.

S1: Oh, I see. That's [what] we had a problem with [|...|]

TA: Yeah, same way right here. [Then go-]

S1: Is that after we outline- do- do we take the measurements after we've outlined the block?

TA: [Except for] this step you don't have to measure. You don't have to measure the angle. You just- you ju- just record this down. What's the- how the incident, how [the] refracts [out], how the refract,

S1: Right.

16:14 S1: So it's bending toward the normal.
(long pause)

TA: Y- you circle the choice here, towards, yeah, the normal.

16:57 S1: This is the uh, this would be the- this would be the refracted.

TA: Yeah, refrac- refracted

S1: This is the refracted ray [...]

TA: Refract (laugh) How to pronounce? (laugh) Reflect

JS: Reflected,=

S1: Reflected, refracted

JS: = refracted.

S1: So I just wanna ask um, does the ray [entering index]

refract to or away from the normal of the surface.

If this is the normal of the surface?

TA: No, this is surface.

S1: All right.

TA: Normal of the surface is here

S1: [...] normal is parallel?

TA: No, normal means normal to the— perpendicular to the, surface. That [means] normal, yeah.

S1: [That'd be normal, yeah.]

TA: So I draw figure out— figure for you. [...]

S2: So is it,

S1: So if this is normal,

TA: Yeah. So this is normal to the surface, right? If [we] come in here, [then] this is normal, right?

S2: Oh, OK. So [this is—

TA: So this— this light, back here, this light go this way.

S1: Now which— now w— wait if [this one— if the normal—]

S2: [This is the normal then.] That's refracted toward the normal.

TA: Yeah

S1: If that's the normal, then um, how is it to or away from?

TA: To or away from, you can— [have] you draw on this one? OK. Put this on, OK? Then connect this lines to this point, right? Connect this lines, to this point. Then connect this two lines [and] this is the outer light going inside this,=

S1: Mhm

TA: = right? So you can see [...]. Then you judge this [if] it's towards or normal— towards or away means, this is surface OK and this one coming, refract[ing] to this way. If the angle is smaller than this one, this mean toward [...], toward [...], [right?]=

S1: [Oh, I see

TA: = lar|ger than,| is away |from|=

S2: [Mmm OK]

S1: [Oh,| I see |OK. Nevermind.]

TA: = [OK?]

S2: |All right.| So we have to do them all.

21:01 TA: This is zero?

S1: Yeah.

TA: [Oh]

S1: 'Cause I mean nothin' reflected off the white card.

You could just see the dot on the card.

TA: OK, let me see this. [Yeah], they were. OK. [...]

S2: What's that? [..]| diffuse [and] the other one, [...]

TA: |I don't know.| [...] check the, first page here. They discuss about [it].

(flipping pages)

S2: There you go. Specular |and diffuse|

TA: |Two kind of-| yeah, two kind of reflection.

S2: [...]

TA: So you - you- you [ju- just] to which kind of reflection [...]?

S2: What would the card be. Dif- diffus-

S1: The card would- diffusion and- what question's [that from?]

S2: What does it mean, diffused? =

S1: Oh, OK.

S2: = What's the word?

S1: Diffused and,

S2: Specular

S1: Specular

23:03 TA: OK, before you do this, have you checked the [answers] exactly from |zero| to 180?

S1: |Yes.| Yeah, we did.

TA: 'Cause that's not one hundred-

S2: Well, that's because we've had this in there.

TA: Oh.

23:46 S1: [When they] ask you to explain results, they say uh, has it- this is the [block]- does the ray entering the block [...] refract toward or away from the normal to the surface. They say toward. They say explain the result. =

TA:Mhm

S1: = Like I have to explain why it's going toward?

TA:Yeah, why it's- why.

S1: Why.

TA:Yeah, you know that this angle is a smaller, than the incident angle, right? =

S1: Mhm

TA:So that's the reason it's toward. So ask your question one more; uh then why this is smaller.
(pause) Have you learned in class about Snell's Law?

S1: Yeah

S2: [Mhm]

TA:So according to this law, n outside- n - n in the air is a one, right? But inside this one, is=

S1: n^2 .

TA:= n^2 . And this way [the] always larger than this one, right? =

S1: Mhm

TA:= [Usually] about one point five, or one point three, but in the air it's one-

S?: [n-] it's like really small

TA:Yeah yeah. So that's the reason why this angle is more small.

S1: [But] the fact that this subs- that this whatever this substance is has a uh larger, =

TA:Yeah, a larger

S1: = quantity, but- what do they call it

TA:[Index, yeah index

S1: index

S2: So couldn't we just write down, Snell's Law, or whatever that is?

S1: [...]

TA:[...] the index of this [material] is larger than [in] the air.

S2: [...]. Oh, OK.

TA:[So-] yeah

S1: [For it leaves]

TA:Same- same way for the second part.

S1: For the way it leaves, is it the index of the

materials |[...]

TA: Yeah, larger than outside

S1: [in the air] Yeah, when it comes out

25:20 S1: Is this a question or is this just- I mean are we supposed to do somethin' here, [n] is that- |or are they just showing us that?|

TA: [No, no,] no.

S1: OK

TA: [You use that] here.

S2: [All right.] I didn't know if we had to,=

TA: Use this art; you can |either way. You can use this one| or also use this one.=

S1: = |Re-enact the experiment on it?| OK.

TA: = It's the same.

25:49 TA: Here, before you do this- this part, you [set? adjust?] this one exactly, going [in] zero degrees out 180.

S1: Do what now?

TA: Yeah. I mean [... incident] ray going in at zero degrees, outside- out at 180 degrees [(CRASH!) ...] That's [better]. Because this times you- you should- you want to measure the angle.=

S1: Ohh

TA: = When you set the white paper on there you need not know the angle- what's the exact angle, so you- if- if this is [enough] straight it doesn't matter,=

S1: Ohh

TA: = but here you want to measure the angle [... seven?]. It's exactly angle,=

S1: Oh

TA: = zero and 180. [All right?]

27:08 S1: [... you had set in here, right? ...]

(pause)

TA: [...]

S2: [Just go down ... of these on both of these part?]
 TA: Oh, here. You need not to draw the figure every times. You just set this paper on there, and let the light go in. [at] zero degrees=
 S1: Mhm
 TA: = and out at 180,=
 S1: Mhm
 TA: = OK? Here it says the orientation of reflecting surface means whatever [... we] have zero, 180, right? So 120, is here.=
 S1: Mhm
 TA: 120 and 300. So here, then you [read]: What's the- what's that angle? [If] this [incident always] zero, right? [So it's [...].]=
 S1: [Tha- that's- that's [what I-]]
 TA: = OK. So this is the direction of [...]. The [direction of-]
 S2: [The angle?]
 TA: No no, this is direction.
 S2: Sssixty-eight- sixty-
 TA: Yeah, sixty-eight, degree, you just [write the ...] in degrees. So six degrees is the direction of the refracted one. And direction [of the] normal is [to 120], right? And minus 80- 80- um minus 90- 90 degrees, it's the normal, right? So it's 30 degree is the direction of normal. So reflect angle is reflect beam between the, and, the, normal. So it's [...], what's the [...] again?
 S1: (murmurs)
 TA: So it's- this times you don't have to draw the [figure there], you just read [...]. It's very [...]. Otherwise you will [...] times.
 S2: All right.

29:16 S1: What was the next part- I mean reflected beams alone? [Two refracted, two reflected ...] So, what do I- there's only- shall I put "two" down?
 TA: Two, yeah.
 S1: All right.

TA:How many refracted, not include |refract
 S1: |And that- that's the- that's the rer-,
 TA:Yeah, this's the refracted, yeah
 S1: Refracted beam. This is reflected.
 TA:[It's the ...]
 S1: All right. So what I [want] is two.
 S2: So is what I wrote, what it is? Is that right?
 TA:Hm? [You're? what?] on this one?
 S1: Yeah, the thing is she- we- we're still doing-
 S2: Yeah, I have three images.
 TA:Yeah, it's two.
 S1: |[But it's- that's only two.]|
 TA:[...] how many refrected beams can |you see.|
 S1: |Reflected.| We're only doing reflected [on this-]
 S2: Oh! We're only doing reflected.=
 TA:Yeah [...].
 S2: = Oh,OK. Well, I wrote down then all- all three
 beams. Is that- is that right though, what I wrote?
 S1: [Yes, the third ...] reflected off the first surface
 in the back.
 (pause)
 S2: Then [this goes to the] reflected ones? (pause) Is
 that right?
 TA:Yes
 S2: OK. Good!

30:55 S1: We have two reflected. Does it matter which one we
 measure? (pause) [...]
 TA:(laughs) Yeah. OK this one [will be ...] problem.
 [...] you see?
 S1: Oh! [I'm sorry. ...]

32:31 S1: So, where do we measure from? OK, it's 59, but do |we
 measure from [...]
 S2: |[Oh, measure from the normal?]
 TA:No. Here i(s) the direction. [We call it] direction is just-
 just what do you read? 59 or 60, right? So that's the direction.
 Then direction of normal, so this is normal, normal is 30 degrees,

right? It's 120 minus 90 degrees is 30 degrees, so the direction of s- the normal is 30 degree. Then the angle of- of refraction [in] - that means between- refract means [n] normal, right? So [... angle]. [an] incident [and] zero. So incident angle is incident ray between- between the incident ray and the normal. So [you? we?] go down here. And 59,

S1: 59

TA: Yeah. And this is 30. Angle of incident- incident is zero, right? It's always [set] at zero, right, =

S1: Oh, |yeah

TA: = |so this is 30. =

S1: Right

TA: = Angle of refraction, between this two directions, so it's uh 59 minus |30.

S1: |30. OK.

(pause)

S1: So the angle of incidence is zero, right?

TA: Yeah, |yeah.

S2: |Zero!?! For all of [...]

S1: They're all zeros?

TA: All zero. No no! This is angle of incident. [I meant] direction of the incident is zero.

S1: So it's 30.

TA: So 30, yeah.

S2: OK. So,

TA: (laughs) Make sure you have them down OK though.

S2: OK, so one more

TA: [It's airconditioned, I'm so hot!]

34:20 S1: [...]

TA: Oh. You're on the second part.

(pause)

S1: [So?]

S2: Is that right?

TA: What's this, five?

S2: Five.

TA: Hmm no

(pause)

S1: 110.

S2: Mhm.

S1: [...] OK. So,

TA: What's the angle here?

S1: 185.

TA: 185. OK.

S1: OK, I see. It would be, - this is the normal so this is the - the angle that we want, so that | would be, 15. |

TA: | Yes; yeah, | yes.

S2: OK.

(pause)

S1: OK.

TA: So here, direction of normal actually is two, right? [... one] is uh 110, so it's 20 degrees. =

S1: Oh

TA: = So 200. =

S1: Yeah

TA: = So this surface out to this side normally 200. [...] for this side it's uh 20. | So -

S1: | What do we do right here?

TA: Oh. One two - one is for sine theta 1. Column one you fill out - fill in the sine theta 1. Then for two, you | have; sine theta 2. Then three, [you have? use?] sine theta 1 over sine theta 2.

(long pause)

S2: OK.

36:07 S1: [...] uh, there are no reflections for this. Only - only one point; that's [where] the light hits the,

TA: Reflection [means] how many you can see, [yeah.] There's no specular reflection. Right? No light is [point -] there's no point here. =

S1: Yeah.

TA: = So that means no specular reflection, but, there's reflection down there, you see? It - it's - it's really down there. So it's this kind, this [it] diffusion. [Look back, here.] There's two kind of reflection.

S1: I see.

TA:OK.

S1: So, that's this- this is this um, this has specular reflection and [this has diffusion]

TA:Yeah, this one has specular, right?

S1: I see. So it's that um [...]

37:54 S1: [...] So the only one we had off was this one.

TA:Mhm

S1: The rest of 'em are [almost the ...]

TA:Express in degree.

S1: [...]

TA:Accuracy. W- one means 100 percent off.

S1: Hm?

TA:100 percent off?

S1: Well no, it's- it's almost- it's a hundred percent right. Except-

TA:(laughing) 100 percent right! |OK, OK, yeah

S1: |Well, isn't it?

TA:Yes, but [...]-

S1: That's what it's supposed to be.

TA:But he asked what's the accuracy. So it's- express in degree means- you see, this is one degree off, right? This is |[...] so-

S1: |So I put "one degree| off"? "Plus or minus one degree"?

TA:Yeah, plus or minus one degree. That's what he ask.

S1: OK.

38:53 S1: Now we should start out with the ones that they give us right here?

S2: |I wanna copy that down. Your graph.|

TA:|Hm? Yeah, one hundred ten.|

S1: |[120, 120]|

TA:120, OK.

S1: Should we turn- it doesn't make a difference [right] where we are on the plexiglass block, right?

TA:It doesn't make a difference because it only concerned about refract one. You're not concerned,

(pause)

S1: Can we use- we use this to mark off-

TA:Mhm, mark off what's the refract angle

S2: We've got two of 'em.

TA:Only [recorded] this one, the strong one.=

S3: OK

TA:= This way if [...]. (pause) fifty-nine. (pause)

Then, you- you need not to draw this one; just read from here.

S1: All right. That's right, it's just all the way around this thing. Yeah, I see. It's 59 degrees.

S3: 59 degrees.

TA:No no no no

S3: But- that's right, it's from- from- from the-

TA:Yeah. Direction [is a] 59 degrees.

S3: Yeah.

S1: OK.

S3: And then- then we in- then we- we compute all- we have th- we have the direction of the normal so- normal surface, then we compute all these out?

TA:Mhm.

S3: I see. But still, we put down 59 degrees.

TA:Yeah. This is the dire- direction. Then what's the direction of [the] normal?

S1: Um it's- that's the exact opposite [of this one should be. So it's 40... it's 180...]

TA:You show- what's the direction of normal? You show me, you [just show me.

S1: |Yeah, it's 90 degrees- 90 degrees [...] that one, so that should be uh 30,=

TA:Yes.

S1: = 30,

S3: 30 across from... 30-210.

S1: Yeah, 30-210. (pause) So we just put down 30-210 [or something]?

TA:Yeah [...] probably just- you just record down 30 because [the with given the consider] the refracted ones [...] from this side.

S1: Oh thats true. OK, we're only work: Yeah!

S1: Oh, not from the- not the [...],=
 TA:Yeah.
 S1: = I see. So it's 30. Same thing.
 S3: [Oh, ...] the graph.
 S2: Yeah, 'cause the-
 S1: And the angle of [refraction] would be 29 degrees.
 Or- it's hard to read my writing.
 TA:Now w- what did you [learn] in class.
 S1: Hm?
 TA:Wha- what's the relation between incident angle and
 [then] refract angle?
 S1: Um they should be |about- they should be-| they
 should be the same.
 S2: |They should add up.|
 S3: Yeah, just [them s-]
 TA:[...] Yeah this probably just verify this law. It
 means incident angle is uh exact equal to the refract
 angle. But here, it's the measurement with error,
 |so,=
 S1: |Yeah
 TA:= not exact same, but you can see, it's pretty
 close, right? OK. Then you change [your? the?]
 angle and verify it again. Sometimes the- maybe
 this angle- this
 law just- just uh [veri for] small angle not for
 large angle, so you-
 S1: Yeah
 TA:next step so you just change angle and for seeing,
 how 'bout that angle.
 S3: All right.
 S1: And [...] should we do, um, just these three?
 TA:Hm?
 S3: Do we do just these three?
 TA:Yeah, all these three.
 S1: All right.
 TA:We change- it's- [it's ...]
 S1: Yeah, it'll go real quick.

43:06 S1: So it's 360 minus 290, so that'll be, between zero

and back to 290, [...] 110.

S2: Are you sure?

S1: Yeah, I think so.

S2: How do we figure out the angle of incidence?

S1: |Oh, no we don't. [refract] 20 degrees. You're right, 20 degrees.

TA:The direction of [...] is 7.5?

(pause)

TA:What's this [angle]?

S2: Huh?

S1: Yeah, that's what it is; I don't know if it's right.

TA:What's the refract one? Refract one— refract one is here, isn't it?

S1: Mhm

TA:So what's the— what's the— what's the [...]—

S1: Don't you just measure it from the normal?

TA:No. Direction you just measure the |[...]

S?: |[Why don't you reach ...]

S?: All right.

S?: It's 186.5 there.

TA:And you calculate what's direction of normal [...] then take the difference between, the direction of normal and the direction of refraction.

S1: All right. The angle,

S2: So it should be,

S1: Don't we measure this from the normal?

S?: The refraction's gonna be [...]

TA:Angle of incidence, yeah, from the normal.

S?: So it's 13.5 |here?

TA:|No no no no. Oh— no no no, angle of incidence, it's uh 20, right? |Because incident [...]—

S?: |Yeah, I can see that. I'm talking about this one.

TA:OK, OK. This one— this one— 20 degrees, it's for this side.

S?: Right, and it's |200—

TA:|200 for this side

S?: Right.

TA:[...] big difference between 200 |and [...]

S?: 200 and 186 is 13.5.
 S?: [That's ...] that's what I thought.
 S?: [All right, all right.]
 TA: Yeah, and then—
 S?: OK, I see the difference here|
 TA: yeah, one is— one is| the sine theta one, two is
 the value of sine theta 2, and three is the value
 of sine theta 1 over sine theta 2.=
 S?: OK
 TA:= OK?
 S?: OK then, so it's— so it's sine,
 TA: Theta 1
 S?: OK. Thank you.

45:08 TA: You're doing very quick.
 S1: Huh?
 TA: You're doing really quick.
 S1: Really quick?
 TA: Uh-huh.
 (pages flipping)
 TA: Yeah, you can finish all. It's very interesting the
 last part.
 S1: The last part of it?
 S2: That's not fair everybody's [? so fast]
 S1: Yeah!
 TA: That's fair! You can learn more!
 (laughter)
 TA: Right? You pay same tuition and gets more knowledge,
 (laughter) [...] not for you!

46:42 S1: ...60, so we get the same thing. We should get the
 same thing, right?
 TA: Mhm
 S1: It's 120 minus, 60. OK.

Tape: TA1 Side B

- 1:10 S1: [Are] we s'posed to use the angles for our graph or [use]
the sine?
TA:[Yes,] sine.
S1: Use sine for 'em?
TA:Yeah.
S1: OK.
TA:There's no, obvious relation between theta one and theta
two. |[...]-
S1: |OK.
TA:Between sine theta one and sine theta (two) [this is
true value].
S1: OK.
- 2:12 S1: Is it all right that we um, find the exact center of
the thing as we measure it out?=
TA:Mhm
S1: = [Wall mark]=
TA:Mhm
S1: = This plexiglass [...]
TA:Yeah, it shows [that] exact.
S1: Yeah, it's exact center.
TA:Mhm
S1: [And so put this sill] underneath the, light. So, as
long as it doesn't come- as long as the laser's,
underneath that, we're fine? Or if the laser's above
the mark, we're fine?
(pause)
TA:Oh. I think that's OK. That means it's at- at the
same [...].
S1: Hm. All right.
TA:Mm. [If I set it] over 120 and [110], what's the
angle here on this side?
S1: 110- 110 to 90.
TA:Yeah. [...] 110 [here]. This time you, only need to=
S1: [...] use |the refracted.
TA:= |measure the refracted.

3:33 S1: We're approximately 186
 ??: One-
 ??: Mhm
 S1: OK, so it'd be...((mumbling) ... so this would be
 ...) that would be 20.
 TA: Two- yeah, twenty for this side.
 S1: Yeah.
 TA: And then,=
 S1: Then,
 TA: = 200 for this side.
 S1: Oh I see, yeah.
 TA: So the angle [of ...] this [way? one?]
 S1: It's right where it's [perpendicular] to this side, we
 take the normal from this side?
 TA: Yes, [...].
 S1: All right.
 TA: But when you consider the, angle of incident, you
 consider the normal is 20. The incident zero.
 [[That's fine? why?]]
 S1: Oh, OK. Just take it from the incident.
 TA: Mhm.
 S1: I see. Angle of incidence would be...((mumbling))
 TA: Angle of-
 S1: Even though- even though the um, even though the
 direction of normal of surface is 200,=
 TA: Mhm
 S1: = the angle of incidence would just- would be 20
 degrees?
 TA: Yeah, 20 degrees.
 S1: All right.
 TA: Because incident always zero.
 S1: Yeah
 TA: Direction of incident always zero, so, normal is 20
 so, incident angle is 20.
 S1: All right.
 TA: So this- the refraction angle [...] here. This is
 refraction beams, this normal beams, and the angle
 between them, so it's 200 minus, 106.
 S1: [...], yeah.

TA:Mhm

S1: OK, so-

S2: [...?]

TA:For one two three here, the columns, one is the value of sine theta one. Two is the value of sine theta two. And three is the value of sine theta one, over sine theta two.

S?: Nokay.

5:28 S1: So we rotate it this way, until it disappears pretty much?

TA:Yeah. Either way you can [...]. But this time you shoulda had this one at the center. OK, otherwise, incident [here] not normal to the- to this surface. [...] incident is not normal to this- this surface, so we shoulda set this one exact [...]

S1: Yeah.

TA:Then you change angles.

S1: OK.

TA:This [...], (pause) [...] ? |[Disappeared.] =

S1: |Yeah.

TA:= This is refract one. Right? Refract one disappeared, so, this is critical point.

S1: So what's that about, 135 and, 315?

TA:Mhm. Yeah. 135 [...]. And this time you judge what's the, incident angle.

S1: So then the incident angle would be um, (pause) 310, =

TA:Mhm

S1: = let's see, not 3- 315, plus 90, which would be, like that, right?

TA:Yeah. Then this is zero. Incident beam always zero. Angle [...]. Yeah, that's it. [Well no need] to calculate, you just, go this way.

S1: OK.

TA:Minus 90 degrees [...] then, [...]

S1: 45.

(pause)

TA:45. (pause) From the critical angle you can get the, index, right? Then you compare the results you get

in the, previous part. [And then,] see how accurate you get.

S1: OK.

8:29 S1: Angle, of incidence, where are we at. Should we use reflected, uh beam for angle of incidence, or should we,

TA: No. |[...]. You find out what's the normal to this.|

S1: |The ang- angle of incidence [...]|

S2: |[... on]| the opposite side would be 40.

TA: 40, so the incident angle's |40 degrees.|

S2: |So it's 40. All right.| So we use the [incident.]

S1: And- oops! That's it. OK. Now what's the angle of refraction?

TA: Angle [... -s two,] right?

(pause)

S1: [Six degrees.] All right. Actually, why don't we just go through all of these then fi- can- can we go through all of these |[then find-]|

TA: Yeah, [you can do all this then ...]|

S3: |OK, all righty.| What's the next one, 150?

S1: Yeah, 150

9:24 TA: Oh, no. This graph ask you to draw the- the sine theta one versus sine theta two, |not| just angle.

S1: |Oh.| OK.

TA: 'Cause angle has no relation.

S1: Oh.

TA: OK. See, actually this is to |verify-

S1: |No relation.

TA: Between angle. (laughs) This is to verify the S-Snell's Law. Right? =

S1: |Yeah, OK.

TA: = |[... what's] sin theta one over sine theta two [but], equals to n1 over n2 [...]. N1 n2 is a constant. So sine theta one over sine theta two is constant all the time. =

S1: |OK.|

TA: = |OK?| There's no relation with the theta. |OK?|

S1: |All right.|

10:02 S1: Well, it's going to be a, linear relationship though,
won't it? It's going to be a linear relationship |[...]|

TA:|For?| For?

S1: For? When we graph the sines.=

TA:Yes.

S1: = It'll still be lenear- linear.

TA:Linear, yeah.

S1: OK.

TA:Otherwise the Snell's Law is not exact.(laughs)

S1: Right. Well [how-] our graph came out almost linear
when we were just, doing the uh angles.

TA:Really?

S1: Well, give or take a little bit of error. But that's
a fairly-,

TA:[...]. Yeah it's not- it's not a good |[...]|

S1: But it'll be better when we use the sines, right?

TA:Mhm

S1: All right.

TA:It's correct to use the sines! (laughs)

S1: OK.

TA:OK.

12:39 TA: [|? do the whole part.]

S1: Aw, do we have to do it?

TA: Yeah.

S1: Why?

TA: Yeah.

S1: We have to go.

TA: You have to go? It's, (S1 laughs, kind of) a two
hours lab (laughing) you see;=

S1: |Two hours!|

TA: = |there are| 40 minutes left. |You should try.|

S1: Well, this |is punishment because we get done early.|

S2: |Nobody else is doing- nobody else has got|ten this far.

TA: No. There's uh, several groups last semester they

- can. Yeah but, all those people [...] they try to finish so they, stay until finish.
(S1 sighs)
- TA: It's very interesting. If you- if you (S1 laughs)
[...] just see that. [...] set [it] up and see what happen. OK? (pause)
- S2: But- I mean, it was the same thing that was on the slide show.
(laughter)
- TA: [Cannot] see the slide show. That's by yourself you see (laughing). Just like you see a lot of- you s- watch a lot of movies, but you can never be actor, right? Now you're actor, not, watching movie, totally different!
- S2: Well can we do it without writing stuff down? Can we just-
- S1: I mean do we-
- TA: Hmm.
- S1: |[...]|
- TA: |Yeah,| try your best. I hope you can write this whole thing down (laughing) start and finish all part.
- S2: OK. But that means we have to be here till six.
- TA: Mhm.
(pause)
- S1: [That sucks (laughing)]
- TA: It's the weekday- weekend, I know.
(S1 and TA laugh)
- TA: It's |too late, I know.|
- S1: |Fridays from four| to six|, is a|- Yes! This is terrible!
- S2: |It's 85 degrees| outside.
- TA: Maybe change [...]- change [your] time schedule next semester.
(laughing)
- S1: (laughing) Yeah. I'm not going till six o'clock on Fridays, that's for |sure.|
- TA: |OK,| let- let me show you just a little; it's very interesting. First I'll tell you, what's- what's in there?
- S2: That's the um, that's the lines.

S1: The lines.

TA: The lines, yeah. OK, [put] here.

(pause)

S2: How close do you have to have that to the, laser beam? Pretty close?

TA: It doesn't matter.

S2: Doesn't matter?

TA: Yeah, doesn't matter. (pause)

TA: [You ...] all this from the lecture? About (pause, putting equipment together) It's spread out [...]. (short pause) It's hard to experience very- if- if you want to really exper- e- experience, you need a, knowledge of quantum mechanics. (short pause) What's your major?

S2: Architecture.

TA: Architecture. Yeah, those students, say, it's no need to (laughing, S2 too) study this one [architecture]. OK then, [use] this one to narrow them. Only- OK, brace this one.

S2: Except you- don't you wanna- [...].

TA: Narrow this one.

S2: If you put it closer that way will it get narrower?

TA: No, no no.

S1: You mean you raise [it higher?

TA: Higher raise, oh |yeah.

S2: |OK.

TA: Raise it more. (pause) Oh.

S1: We missed |this one here|

TA: |Missed, yeah.| [We] missed one.
(pause for more assembly)

?: Hm.

(pause)

TA: OK, just leave like that. OK, then you use the, [covered] glass. Right. It's 50. [(mumbling) Can you move it this way? It's about five roughly.] OK, first you measure the distance between this one and this one, and set it [as] 50 centimeters. That means this ray, this light ray going this- out [...] this- [... -ess] parallel. Isf- If this is focal point,

[like this] is parallel lines.

S2: So does this have to be 50 centimeters from this then?

TA: Yeah, this one. You set it parallel. Second part uses parallel lines to get, what's the focal point of another... (more assembly) Here just assume this are parallel, OK? Then you move this one.
(pause)

S2: [I'll] move them

TA: OK then, measure the distance between here; that's the- this's the focal length. OK? =

S2: [Yeah]

TA: = [The ... amount] is like five centimeters, because this one really not has- [have ...] exactly 50 centimeters, so [...]. So, it- it- it won't take long time you maybe; just five minutes you can finish all this. OK?

18:05 TA: Finished?

S1: Yeah. But we got different values for these [...] 1.47, two of these are 1.38.

S2: That's so little though. It won't make that much difference, will it?

TA: Yeah, so, why is all same?

S1: Yeah, it's almost- it's almost all [...]

TA: Yeah, so that's the- that's the [...] S-Snell's Law, right? [..]

S1: |[...] specific|- specify it that. But the fact that these are almost 1.5 and these are just about 1.4, is there, like [difference]? Is that- isn't it-

TA: That's error. Because this is experiment |and not-| yeah. |I(t)- it's-| yeah, that's no problem.

S2: |Oh it's just- Oh, OK. Well that's no problem then. We can| handle |that.|

S1: |All right. [...]|

TA: |You| cannot get exactly, because theoretical is exact but it- if you're doing experiment, =

S2: Uh-huh

TA: = it's machine and |then you got human errors,
so,| yeah.

S2: |Oh, OK. So it-| OK.

TA: [Then? And?] you try to figure- try to figure- use
the- sine theta one versus sine theta two.

S2: Mhm.

TA: OK. (pause) So OK, here there's two way. So one way
you get all this one. This way [i-] n.

S1: Mhm

TA: All n, but, they're different. But you cannot say
which way [in] exactly, which way [in].

S1: That's true.

TA: So, how to decide: Usually we take average of all
this, right? =

S1: Mhm

TA: = So that's the value. Another way i(s) ju- just
draw the figure. And get lines which i(s) most
closely to all this figu- points. Then connect this
lines, get [a] slope. [The] slope is the value.

S1: I see.

TA: So you draw a figure, sine theta one versus sine
theta two, =

S1: |OK|

TA: = |and then| get the slope. That's the value, here.

S1: All right.

TA: OK.

S1: Thank you.

19:38 S1: We don't understand why there's no relation. I mean,
you said there was no relation between theta one and
theta two? (short pause) Didn't you tell me that?

TA: Yeah, there's no relation between theta one and theta
two.

S1: But why- I mean, it says,- it says explain why- I
don't understand why it's not.

TA: (laughing) Why it's not.

S1: Well, we don't- |I mean-|

TA: (laughing) |Because Snell-| because Snell's Law's- op, OK,
you can say I try to draw the figure- try to draw

the figure, and see [how ...]. You cannot [...] it's straight or it's [hyperbolic]. There's no relation.

S1: [...] Oh

TA: That's why.

S1: OK.

20:33 S1: Hey um, we measure pretty much from the middle, right?

TA: Mhm. From middle, yeah. (pause) What's this? Minus 20. (pause)

S1: So do I wanna like, figure out how much- how- the spacing between there and [then], the spacing now? Or something?

TA: How you got it this way? You just [add? have?] this on focal, right?
(pause)

S1: What, now?

TA: I mean so how- how do you [have to take this part?]

S1: Find the [...] |so| it becomes a point.

S2: |Move it|

TA: Uh-huh. So, have you tried this one?

S2: Uh-huh!

S1: All right. You have to-, you have to keep |going.|

S2: |It doesn't.|

TA: Ca- can you get one?

S1: No.

TA: Why?

S1: Because it diverges.

TA: Yes, it diverges.

S1: Yeah.=

TA: So-

S1: = So we just have to like sketch it, right? Here?

TA: Yeah, if you- if you want measure this one you need one more diverging part, yeah one more converging lens, put in there. That'd be furthest. And then calculate. I guess OK I show you. If we put one more here, (pause for construction) OK, you can get. [Right]? You calculate this. Because this are parallel lines through here. Then it's diverging,

all right? And you get images h- object here.
 Right? It's diverging. [?] get objects here. [Because]
 this objects through this, converging lens, then on
 focal here. (short pause) I'm not sure, have you
 learned in class about this calculation? (flipping
 pages) [You] see, first it's parallel lines, =

S2: Uh-huh

TA:= OK, through diverging lens=

S2: Uh-huh

TA:= and going this way and this way. And-

S2: Right. Image forms back there. [...]

TA: Image here. So this- there is, minus 20. If- if-

S2: Right

TA: If- you're doing very well, so it's minus 20, OK? [Now
 you saw] at that converging lens then there's one
 going to this one, =

S2: Right

TA:= so, this is a distance [...] image, =

S2: Uh-huh

TA:= [one for]- to this lens, for lens two, OK. Then,
 the distance, of object, is this way. From here, to
 here.

S2: OK.

TA: So if you measure distance between these two for-
 you measure OK d, whatever d o m. Then, this is
 minus- this is you want to solve. This will your
 unknown. You [can] consider it f, you want to solve
 it. =

S2: Right

TA:= So d o equals to d o m plus f. Then d i
 is [your ...] measurement. OK then putting in the
 formula, d1 plus di equals to f1.

S2: Mhm

TA: So you know the f. What's the f1? Wha(t) the-
 what's-what's-?

S1: 5|.4

TA: OK yeah then, this is, 5.4. And this is image
 distance between second [and] last to the, screen.
 [Then] measure this dis- his disan- the

distance between these two lens-

S1: These two? Like this?

TA: Yeah. So, what is [the value input]? (coughing student)

S1: 9.2.

TA: d_1 plus f . Then solve this equation.

S1: Got it. [...]

S2: OK.

TA: So that's why he wants you to draw [the yeah] figure [...].

S1: [... done ...].

24:03 S1: This is pretty fun, isn't it!

TA: You think so? (laughs) I saw you're waiting here.
(pause)

S2: [Well] we're stuck right here.

TA: Stuck, uh-huh.

S1: Oh. You just use Snell's Law.

S2: Oh, that's all.

TA: No [single ...]

S2: So, sine theta two, is, [point 45]

S1: The index of refraction of error times sine [...] is 40.

S2: So what's- that's what we're solving for, right?

S1: I got 1.1 [...]

S3: Sine theta one.

S2: Well-,

S1: The n of air, which is 1.0003, times sine 40 divided by sine 20 is 5. [...].

S3: Sine 40, which was,

S1: [...]

25:14 S1: I'm just puttin', (short pause) for my graph 'cause I don't have a piece of graph paper, is that OK? Or do you want me to sketch it? (pause) Yoo-hoo!

TA: You can [...].

S1: [This is my lab partner('s), see?] I have it [...]

TA: Yeah, I make- cannot read all this; you, take this

home |[...] for [...]– Yeah.|

S1: |Oh! You want me to take it home?|

TA:And [take] all this, the lab report, and [hand it in.]

S1: |Mmm,| OK. No problem. Then I better sketch it.

25:47 S1: All right, we're s'posed to put, [...] the results of
the sines, [...] theta one and theta two?

TA:Mhm.

S1: All right. So, [(mumbling)...]

TA:[Yes, sine theta]

26:34 S1: Is this r– are these the right numbers? D i,– this
is d i, [and] this is f?

TA:No, this is– this d o.

S1: This is d o?

TA:Yeah, that's d o.

S1: OK.

TA:[This– this is ...] d i is– f is [which], unknown
number, right? So f plus the distance between this,
[...]

S1: |OK. This is like–, OK this is [say] d i.

TA:D i, yeah, equal to–

S1: This– and this is f

TA:No, no no.

S1: Oh, OK, d i,=

TA:Equals to

S1: = is f plus 9.2.

TA:Yeah yeah.

S1: OK.

TA:OK. Then, [...] take] this formula f equals to 9.[4].

S1: OK.

(pause for coughing)

TA:D o equals d i plus, d l plus f; d l is distance
between two lens. All right?

S2: So– so this part is d l here, then, right?

TA:Yeah d l yeah. And d i is distance, we measure from
the, [screen,–]

S2: |I thought this is d o.|

S1: Yeah, I thought that was d o.
 TA: Ah that's d o. [?] sorry.
 S1: This total distance is d i, right?
 (short pause)
 S2: Well w-
 S1: From focal length?
 S2: What's-
 TA: OK. [Let me ju-] let me speak again, OK? (laughs)
 D o is object, right? Di|stance| from object.=
 S2: |Right.|
 TA:= Object is here. And here.=
 S2: |OK
 TA:= |So it's the distance, this is unknown f plus the,
 distance between two lens. That's the d o.
 S1: OK.
 TA: OK? |D i means-|
 S2: |So,| from here, |to here, is d o.|
 ??: |[...]|
 TA: |Yes, d o, yes.|
 S1: And this is |d i| right here?
 S2: |OK. OK.|
 TA: |Yeah,| d i is yeah, image, on a screen to the first-
 second lens, so this is d i.
 S2: OK.
 TA: OK, equals to f- here the f is- here the f is
 second- the seconda lens, OK, [...] 5.4 centimeters.
 So d i- d o plus, including two- two part, one is
 the distance between two lens, and the another is f
 [...].

28:40 S1: [...] what do we start on, [...]?
 S2: [...]
 (pause)
 TA: OK, let me- let me show you.
 S2: Yeah, it disappears on the wall. [The refracted goes
 ...].
 TA: OK. So, these are refracted one, this is refract
 one, right?=
 S2: Mhm

TA:= Now I want to see this one disappear.

S2: Yes

(long pause)

TA:[... magic] pencil. [?]

S2: [...] Well, wait. It's right there.

TA:No, this is [reflected] one.

S2: [... I believe you.]

TA:[...?]

S2: I believe you.

TA:(laughs) You believe me?! (short pause) This [time] has two. [...] You see? One, two. This is refracted one, [the] refract one, right? We change... See? This one [is ...], right?

S?: Uh-huh.

TA:OK

S2: [...]

TA:The critical angle i[s], the [time] minus [...]. If you move this way, there's no... [all times]. But |we want- we want point, yeah,|=

S2: |[Yeah, so] just the point right when it disappears|

TA:= yeah, right

30:20 S1: [...]

TA:Yeah. Just locate it. [That's right.]

S1: All right

TA:Try to find, when this point disappear.

S1: Oh OK. (short pause) But-,

TA:OK?

S1: Yeah, I see. But, it's gotta go- |[yeah, this way.]|

TA:|OK, you [.|..]. OK, don' don' don't. Don't touch this [one], yeah. You- you [...] - you [will always have] this part yeah, see where this disappear. [Can] you see that?

S1: Mhm.

TA:Yeah. Watch this [...]. Oh! It's OK it's OK. Back.

Back a ways. Yeah, OK. Move [every ... away]. OK.

[...] you see? [There no one.] Disappeared.

S1: Oh I see. [...] right there.=

TA:Mhm.

- S1: = Which is approximately 40 (pause) [...] actually [48] degrees. So that'd be 40
- TA: So you decided which is the, normal, which is the incident. Incident always zero, right? So then what's the normal? Direction.
- S1: For this? =
- TA: Mhm.
- S1: For as pa- as it is right now?
- TA: Yeah
- S1: [That one] would be um, 138. 138 degrees.
- TA: Ah it's here. But we consider the incident angle so, for this side
- S1: Oh I see, so it would be um (pause) where are we up there (pause) [(mumbling)...] (pause) [So it would be 3-] 312? [(mumbling) ...] 312. [... center ...] (long pause)
- S2: [...]
- TA: [Yeah ...]
- S1: [(mumbling)...] (long pause)
- S1: [Looks like it's better (someone coughs)...one point] 47 here.
- TA: 47's here then, =
- S1: So 47 |here would be-|
- TA: = |plus 90 degrees| to there and [(mumbles)...]
- S1: OK [...]. Um, number 318 (pause) [Well] it's over [about] um 318 over there. OK, so that would be the- this- this would be critical angle, and that- that's your critical.
- TA: No, this is, direction of normal, right? Then you [consider] what's the incident angle.
- S1: Yeah
- TA: [...] this is the in- critical angle, incident is zero. Zero can't |[...]| =
- S1: |Oh, I see. So-|
- TA: = 360 degree minus [...].
- S1: Oh, I see. OK. (pause)
- S1: (to lab partner) Are you still totally lost? So it's

42 degrees.

S2: No. |Actually| I didn't catch what he-

S1: |All right.| All right. Um, since we- we had to find this-You know, I'll just do the whole thing over [...].

TA:[...]

S1: See [here you] got the- this reflection=

S2: Mhm

S1: = and [your] refraction? [...] the, refracted. And then, at that point, which was... [Keep] it in the center. (pause) See, [...] =

S2: Mhm

S1: = That [...].

S2: That's when it's totally- Oh, OK.

TA: So this is critical point. |[...]| incident |[...]|

S2: |OK. So then if you go-| [you just]- oh poop. You just |have a-

TA:|[Here, one point's ...]

S2: Farther than that. Oh, it's still gone?

S1: |Yeah|

TA:|Still| [...]. At| this point here. [...].

S2: |Oh! Gosh.| OK.

S1: All right, then we [simply] take the sine of the,- the, incidence? If |[what the]- [critical]-| critical- critical angle of incidence it'd be one over the-oh, I see.

TA:|One over| sine.
(pause)

TA:|Then get n|. Because n- n is always larger than one. So sine theta is always less than one. So one over sine theta is,

S1: OK, I see.

S2: OK.

36:32 S1: How exactly um, do you calculate index of refraction?
Using the [uh], critical angle? That second technique?

TA: Um it's uh formulated [uh]. one over sine critical

angle, is the, index. On |this one.|

S1: |One over sine.

TA: |Over sine... Incident angle (is) 45, yeah.

S1: Let's try that one instead.

S2: What is it, one over sine 45?

S1: Mhm.

TA: You haven't learned in class?

(short pause)

S1: Uh-uh.

S2: Have we learned that in class?

S3: Yeah, it's 1.4.

S2: Yeah, OK, that's what I thought; there are two |times
sine 45.|

S1: |Yeah, that's what we thought.|

S2: Like I said!

(TA laughs)

S?: No [one ...] you.

S3: No I- No I'm the one who figured it out so,

S2: I figured it out; he doesn't know what he's doin'! He
really |[doesn't].

TA: (laughing) |What's your name; I will- I will try to
remember your name so, (laugh) I can judge who is-
(laugh) which [will] get a [better] score!

S3: Hey, I'm the one getting the A in this class, so
|that's [why]-

S2: |Oh, are you?

(laughter)

S3: Yeah.

S2: (laughing) Yeah, yeah, you are! |Yeah, you're| not!

S3: |I am!| You wanna walk out and look at it on the board
right now? I will show it to you on the way out.

S2: (still laughing) Yeah, you're not.

S3: How much do you wanna bet?? I swear to God I'm
getting an A in this course, so get off my back.

37:56 TA: OK, [they're asking ... times ..., ...] the last
part, OK?

S1: Nah!

(laughter)

(pause)

S1: What's the last part?

TA: It's the later. [This time ...].

(pause)

TA: OK. [...] (pause) You see, only one.=

S2: Mhm

TA: All right? (laughs) [So you put this] on there.

(short pause) How many here?

S2: Quite a few.

S1: Quite a few, yeah.

TA: Ohh. It's the way [this light] comes in. Do you see?

S2: Why does it do that?

S3: Well, because of the um,

S?: Spectrum of the light.

TA: (laughing) Why?

S?: Well that's ob|viously-

S?: |[... it's-]

TA: (laughing) It's obviously, yeah.

S?: There's 300 lines per inch there. How do I know that? I don't know. (laughter) 'Cause it's written there [...].

TA: OK [you say], 300 lines per inch, [...]

S?: Well this obviously has something to do with the [spectacle there].

TA: OK, so re- if you [don't] want- really understand this, you need to take the, physics uh five one eleven?

S?: Physics 511?

TA: Yeah. |Quantum mechanics.

S?: |[...]

S?: Yeah, I might be around for that.

S?: I'll sign up for that tomorrow!

(laughter)

S?: 500-level physics.

TA: Then if you change directio- change the pla- distance, then you will see. The distance [between] will change.

S?: W|hy?

TA: |Why?| (laughs) Ho, why?!

S?: (laughing) Yeah!

TA: OK, this- you just observe, (all) right? So this-

S?: OK

TA: = you feel interesting, that's all. OK? Then, have
you learned- you have learned in- in class about
the, converging lens,=

S?: |Yeah. [...]

TA: = |and diverging lens? OK, then, I will show you
how- that means, diverging- or converging lens.
OK, this a-, what is-, positive means what?
Converging, right?

S?: Right.

TA: OK. Over here... Can I take this off?

S?: Oh yeah. We're done with it! (laughing)

TA: [I'm gonna take this off.] (long pause) Not exactly,
just... (pause) You see? [Put] this in, conversion.
You see? [... this here. Not at this one point, not
... further, right? ...] 15 centimeters, you
see? =

S?: Oh!

TA: = It's converging, right? =

S?: OK, yeah.

TA: = So let me [...] change it [...].

S?: Hold on, where's- where is the 15 centimeters?

TA: Yeah you can check. How long is it? Only ten!
(laughter) Well that means, this coming, lines is not
parallel, then|- then we [are] converging=

S?: |Ohh

S?: |Oh, OK

TA: = |every 15 centimeters per cen- second.=

TA: = This is ten, so I'm going to change this to...
[(mumbling) ...]. [If you'll] set this up, [OK?]
(pause) Yeah. (pause) OK.

S?: 14.5, [oh yeah].

TA: That's good enough, huh?

S?: Yeah, that's good e|nough.

TA: |OK. Then I change this [one]- this diverging one. Take
this off.

S?: OK.

(pause)

TA: [If I take this off], can [I] get point?

S?: Well it could on the other side.

(laughter)

TA: Yeah, yeah! So that means so this is diverging, |yes,=

S?: |Diverging, yeah|

TA: = |because cannot- [...] can't be parallel.

S?: Yeah.

TA: Diverging, right?

S?: Mhm?

TA: [Can that make] sense?

S?: Yeah, that makes sense.

TA: OK. Yeah, it's almost time.

42:37 S1: My prelab's the first page of my lab, so I'll just
turn that one in together, OK? You can tear it apart
or, whichever.
(no audible response)

42:56 S1: Thanks for letting me start that lab late because I
woulda been (in) a lot of trouble if I couldn'ta
gotten this lab |[this time].
TA:[But] don't be late next time!
S1: I won't!
(TA laughs)

43:42 S1: So, you don't want these from me, you just want me
to jot it down on my, [real lab]?
(no audible response)
S1: [OK, then, I'll get it in...]

44:22 S1: [...], and um here's the other uh, I'll staple it.
TA:[Where's] your name?
S1: Hm? [Is] the name on ['em ...]?
TA:No.

S2: [... back.] [...], where's the front page?

TA:I don't know.

S2: All right, well it's- I'll just put it [...].

TA2 Transcripts

Name of Class: Physics 111

Date of Observation: Wednesday, 19 April 1989

Tape: TA2 Side A

5:52 TA: Did the beam strike at the edge or=

S1: Yes

TA: = one of the surface?

S1: Yeah, it's striking right at the edge, right at this corner.

TA: Hmmm

S1: Is that where it's supposed to hit?

TA: No, it's not.

S1: Wasn't it supposed to hit there?

TA: You have to- the beam have to strike one of the, surfaces that are over here.

S1: We [had] it like that so it came out- we had it right on the edge so it came out these two sides.

TA: OK, but-

S1: Use- use one edge?

TA: For this case what are you observing? (short pause)
You're observing the defraction.

S1: mhm

TA: So you have to consider the defraction angle.

S1: OK. 45 degrees.

TA: That's- that's the incidence angle.

S1: That's the incident. OK.

8:18 S1: This is your normal, right?

TA: Sorry?

S1: Is this your normal to this?

TA: Yes, that's the normal to the surface.

S1: When they're talking about these rays, this ray entering the block, [draw] on the graph toward or away from the normal of the surface, which way are they talking about, this way or this way?

TA: Umm

S1: Oh this is the way.

TA:What is the incident beam?

S1: The incident beam [I guess] is this one.

TA:OK, [if] that beam strike this surface, and the normal to this surface is this line,

S1: Right.

TA:Right? Then the question is, if there was no block, then the beam should go straight ahead.

S1: Mhm

TA:But because of the block, does it go toward this line or away from that line?
(long, thoughtful pause interrupted by the arrival of the lab partner, late to class)

9:56 S1: Which was the normal to the surface?

S2: That would be straight through that way?

TA:Yes, there are two normal to the surface. This is— one of them is this line and the other is this line.

S1: Right. So how do you decide if this is away,=

S2: |or toward|

S1: = |or |towards

TA:Um, imagine the case when there was no block, then the beam have to go, straightly, but it bent here.=

S1: Right

TA:= But did it bend towards the normal or away from the normal?

S2: It bent away.

S1: It bent away, right?

TA:No

S2: 'Cause it came this way?

S1: The normal's that way?

TA:This is the normal, and this is the beam. If there was no block, it have to go straight ahead. But it bent, towards the normal.

S2: Oh, OK

S1: OK

TA:But, if the index of refraction is smaller than one, then what would happen?

S1: It'd bend away?

TA: If the index- index of refraction of this first beam
is smaller than one, smaller than the air

S1: It shouldn't bend at all there.

S2: Yeah, it shouldn't bend at all.

TA: It shouldn't bend at all?

S2: If it's less than, it'll bend away.

S1: If it's less than, it'll bend away from there?

S2: It's like water going to air?

(short pause)

TA: OK, this is the case. Here the index of refraction is
greater than one, =

S?: Uh-huh

TA: = and the index of refraction =

S?: | is one, yeah

TA: = | is one, and the beam is going from the index of
refraction is greater than one, to air, where the
index of refraction is one.

S?: Then it's one.

TA: Then did it bend away, or

S?: Oh, here?

TA: Yes.

S?: Away.

TA: Away. Right.

S?: So when it goes from a higher to a lower, it bends
away?

(TA nods)

12:07 S1: Do we only have to hand in one drawing?

S2: One of these, right? Only hand in one drawing, right?

TA: Ah, yes.

S1: But we both fill out the lab report thing, right?

TA: Sorry?

S1: We both do the whole report, don't we; we don't hand
in just one these, right?

S2: Or we don't-

TA: Yes, just hand in one of them and then write down
your lab partner's name.

12:28 S1: Can you explain why it's doing this? The ray entering

the block, refracts, away from the normal to the surface.

TAWhat is your question?

S1:I s- we see why it does that but why- I mean we see that it does that, but why does it do that?

TAWhy- why does it bend toward the normal?

S1:Yeah.

TAUh, that's because of the difference of index of refraction,=

S1:OK

TA= between air and,

S1:Is that the same thing for why this does that away from it?

TAYes, that's the same reason but, depending on from where to where the beam goes, there's a change in angle,=

S1:OK

TA= direction of the angle.

(S1 writes the response down as the answer to the question on the lab report.)

S1:All right.

TASo to bend toward the normal to the surface, does the index of refraction should be greater than one, or smaller than one?

(pause)

S1:What'd you say?

TATo bend toward the normal to the surface, um, is the index of refraction of this plastic |should-|

S1:|Is greater, isn't it?

TAGreater than one? Should it greater than one?

S1:Is that right or not? (clatter from object dropped on neighboring table) Huh?

TAYes, that's right.

S1:OK

14:57 S1: How close does our predicted angle up here really have to be to what we get? 'Cause it's not- it's more like 30 degrees in here; it's a little high.

S2: Yeah, we had 28. That's almost a 30-degree angle.

TA: Ahm. You're doing the [first] part? This one?

S2: Yeah.

TA: Yeah. For this case, angle- you will- you will do this experiment for later case than this one, and in that case you have to measure the angle, but for this case-

S1: Doesn't matter?

TA: [Doesn't matter.]

S1: [I mean, I just wanted to see it for an estimate

TA: Just- just answer to that question. I mean, does it bend toward to the normal to the surface or away [from the normal to the surface?]

S2: [OK. That's fine right here.]

TA: [Any]way, this picture is not quite the same as this one, isn't it? (pause) [They're all-]

S1: [No, be]cause this one comes out here. This is- but isn't there another point in there, the light is bouncing back? I guess that's where I- this picture I drew is wrong.

TA: There's another point? Where? Oh, [here it is]

S2: Here's one.

TA: There's [n]one

S2: There's the one, right here that-

TA: Yeah, then where [is this beam from?]

S2: [It comes- it comes] straight out, it looks like. You can see the line, I think.

TA: Where is this beam from? What kind of beam is this?

S2: This one?

S1: That one's ref- reflected.

S2: It's just a reflected beam.

TA: Right.

S1: You mean this one is our refracted?

TA: Right.

S2: We've done refracted and this one's reflected, so, right?

TA: That's right.

21:15 S1: They want the direction and degrees, in here?

TA:Y|es.|

S2: |Like| if it was 190, that would be about, uh,

S1: That's 180, I think, actually,

S2: So we just write 180?

TA:Yes.

S2: OK, that's a reflected beam?

S1: That's the reflected beam.

TA:That's the reflected beam, and that's the-

S2: Refracted beam?

TA:Yes.

S2: So don't worry about [(crash!)]the refracted beam, right?]

TA:No.

S1: So don't worry about the refracted beam.

21:56 S1: It's really close to 60.

S2: It should be like 60 degrees.

S1: 60, we'll call it sixty yyyyeah.

S2: Should we put 61 or 62 if that's what it is, or
should we just put 60?

TA:Write sown what you observe, what you measure.

S2: Direction of normal to the surface. Does that mean
this one?

TA:No. The normal to the surface always perpendicular to
this surface, |so-|

S1: |That| would be 90, wouldn't it?

TA:90?

S1: Or the direction on here is [outward], isn't it?

TA:If this is zero, then, the normal to the surface
should be perpendicular to this, so-

S1: It would be 30.

TA:This is 120?

S1: Minus [...]

S2: Thirty, angle of incidence is this angle here, right?
This angle right here?

TA:Right, the angle between the incident beam and normal
to the surface.

S2: Oh, the angle of the beam right here?

TA:Right.

S2: So it's 30 degrees.

TA: Yes. That should be the same as direction to the normal to the surface.
 S2: And then angle of refraction is this [one] right here, off the angle over there, which is 30 again.
 TA: Yes, that- that's supposed to be 30 but-
 S1: [With this block] it's 28.
 S2: Yeah it's 28.
 TA: Right, there can be errors.
 S2: OK
 TA: So [there you can underneath] this blank.
 S2: Just leave that blank?
 TA: No, I mean this error.
 S2: Oh, OK

23:54 S1: This is diffuse?

TA: You probably have handed in your prelab, didn't you.
 S1: Yeah
 TA: There is- there is something like this [...]. One is diffuse and the other is, I don't remember.
 S2: Those two are about [...] specular and uh diffuse.
 TA: Right
 S1: Specular?
 S2: Specular is [often...]. Yeah.
 TA: Yeah. That's just the [...].
 S1: Oh. (laughs) Look at the line right below it!

do you want the degree marking off the sheet? Or just the direction marking?

TA: Um. First you have to set your [poly-...] on- on this table and then you have to [fit] your axis. If this is zero-zero degree, and the reflective beam, is here, then this should- this can be angle. Or you can also set this as reflective angle. So, it doesn't matter.
 S1: OK
 S2: So when it says |[...]-|
 S1: |But when it says| direction
 TA: Direction? Direction can be represented by any angle.

|Any-|

S2: Not |the [normal]?|

TA:All- all directions can be represented by one of numbers,
|which is=|

S1: Oh, OK, |so then it's [possible]-|

TA:= zero to 360

S1: OK. So what angle did it come out at?

S2: [...]

26:08 S1: So when we get down to direction, we wanna call this,
for these coordinates, I mean for this, we wanna call
this, direction from this direction [right] 'cause if
this is 30, 320 by 300 then

TA:right.

S1: Our normal's on 30.

TA:Yes.

S1: So, and if our angle's [...] from the normal is this
far, this is what we're counting on, is that what we
say? Or do we have to say from the normal, away from
the normal?

TA:Um, for this case you have to measure the angle but,
you don't have to consider this part because you are
just considering reflection not refraction.

S1: Right.

TA:So, the surface is around here, and, this is the
normal to the surface, |[so thi-]|

S1: |So you| can count the whole, away from this one.

S2: Oh OK.

TA:Then, what is direction of the refracted beam?-
Reflected beam.

S1: I'm figuring you count out from the normal all the
way back to this position.

TA:Which position?

S1: From the incoming all the way around to the
reflected- direction of the reflected beam.

TA:Ref[la]cted beam?

S1: No, [what it]- reflected beam.

TA:Reflected beam doesn't go through this plastic
block,=

S1: Right

TA:= it reflects, over here.

S1: Oh! [Looks like...] OK. So this is what- we just want to measure this and do whatever measuring, just straight angles? Or uh

TA:Yes. Just imagine that this is [polyco-...] and you don't need to worry about the radius of this [poly...], just concern about the angle. And if the reflected beam goes through there, then the direction of refracted beam is 60 degree.

S1: [...]

TA:And for this case then what about direction of normal to the surface?

(pause 8 s.)

S1: Mm, 30 degrees

TA:30 degree? Here is 30 degree and they are not normal. They are not right angle.

S1: Oh, the normal to the reflected beam?

TA:Normal to the surface.

S1: Oh, surface normal is over here.

TA:No, for this case. for this case, OK. What is normal to the surface.

S1: What angle? Oh, for this?

TA:Yes, this is the surface, and what is the normal to the surface?

S1: 60

TA:Right. 60. So obviously, in |this| case,

S1: |OK.| All right, thanks.

30:09 S1: Did we do this right? If the direction of the beam is 56 and it's- the normal's 30 degrees from the surface, so the angle of incidence is also that and then this minus this would- gives us that.

S2: Well this |minus| the normal.

TA:|Uh-huh|

S1: Yeah, whatever, it doesn't matter [|...|]

TA:|Ye-| yeah, that's right.

S1: OK

TA:Wait a minute. 56 minus 30?

S1: |Would be 26.|
 TA: |Is that [over]| ref[ra]ction?
 S1: |Yeah.|
 S2: |326
 S1: I didn't do the math, I just did [...]
 (S2 laughs)

30:50 S1: We're still confused about this normal thing. I mean is
 the normal there? Or there?

TA: Normal to the surface is perpendicular to the
 sur|face.|

S1: |It's| always 90 degrees then.

TA: No, not 90 degrees. This is the angle. Always
 this angle represent the direction.

S2: Oh.

S1: OK, so this would be, the direction of normal to
 the surface, right?

TA: Right, |right|

S2: |30 degrees|

S3: Is it in degrees?

TA: 30 degrees? Right.

S3: That's right.

TA: Right.

S3: [...] direction, direction isn't in degrees, it's like,
 up down north |south|

TA: |Direc|tion over ref[la]cted beam, what is direction over
 ref[la]cted beam?

S1: Hm? Oh that's where this thing comes out over here
 [...]

S2: Here?

S1: Yeah.

S2: That's a hundred and nine degrees.

TA: This is reflected not refracted.

S1: Oh, sh- (pause) Awright. You were right, we were
 getting two of 'em, and I didn't know |[...]|

S3: |It's| right here. (pause) 60.

32:22 TA: You did this already?

S1: Yeah!

TA: Oh. I missed |these|

S1: |Oh| I'm sorry. I didn't, get you to check 'em.

33:05 S1: Um, the graph should be, the angle- angle of reflection and refraction versus index, or just— just these two related to each other? It'd be just these two related to each?

TA: If you draw a graph with those two numbers, then you will get something strange, because both of them are represented by sine function and they have curves. But, if you draw a picture with those two numbers, then by Snell's Law you'll find the |proportionality|

S1: |[...]|

TA: Right, yes. And the slope or slope inverse should represent the index of refraction.

38:07 S1: Find out where the normal goes [...]

S2: Hm?

TA: |What is—|

S2: |What is| that? [...] let's see (pause) 200. (pause)

S1: It's at 200?

S2: Yeah. |[...]|

S1: |And it's refrac|ted at 185, so it would be 15 degrees.

S2: Yeah

S1: Is that right?

TA: Ah, yes. You also have to write down 200, because you have two lines which represent the normal to the surface.

S2: OK. 200. (pause) OK.

39:51 TA: For this case, um, the angle of incidence should be represented with respect to the normal to the surface on this side, and the angle of refraction should be represented with respect to the normal to the surface of this side. So there should be two direction of normal to the surface. One is this, and the other is

that. And then, this is gonna be, angle of refraction and this is angle of incident.

S1: OK

TA: So that cannot- both of them cannot be larger than 90 degree.

S1: OK. Both of them added together? Or just both of them?

TA: Each of them.

S1: OK

S2: So the-

S1: |That's not right.|

S2: |The refraction| is off of which normal then? |Off the normal to the-|

S1: |[...] which one,| this one? Is it off this [line]?

TA: This is 290,=

S1: Right

TA: = so 200 is going to be the normal, right?

S1: Yeah, OK

TA: Then |this one would be-|

S1: |For 90 degrees.| So this one.

TA: Yes

S1: Thir- that would be thirteen, wouldn't it? Well, 'cause it- we have it at 187, approximately.=

TA: Yes

S1: So that's what it would be then.

TA: No, uh, but-

S1: [For] the normal? 'Cause the normal would be (pause)

TA: This is the angle from, here, isn't it? No? The angle should be just absolute magnitude of those angles. So they should be 200 minus 170. That's angle of re- refraction.

S1: 170? This? Or, 180?

TA: One hundred and- no. I'm sorry. 185. 185. 200 minus 185.

S1: OK. 15, there. OK.

TA: Then what is |angle of re-|

S2: |I don't- I guess| I don't understand why we're measuring it off of this normal here.

TA: |Ahm|

S2: |Instead| of the normal to the face.

TA: Because you have to use Snell's Law. And when you—
when you apply Snell's Law you define the angle of
incident as the angle between the normal to the
surface and the incident beam. And |...|—

S2: |See we—| we defined it as this is the normal, and then
the angle of incidence is from here.

TA: This is angle of incidence, and this is surface, and
this is normal.

S1: Oh, because |this is| twisted?

S2: |OK|

TA: Yes.

S1: The normal's perpendicular to this?

TA: Right.

S1: OK.

S2: OK, that's what I had wrong.

S1: |OK, I get| it. I understand now.

S2: |That's perpendicular.|

43:31 TA: Did you draw this graph?

S1: No.

S2: Uh-uh. Nope.

S1,S2: (simultaneously) Why, is that right? (laugh)

S2: What did it get?

TA: You have to do your own.

S2: Well, it must have been good!
(laugh)

S2: Well, let's see, it looks something like this.

44:27 S1: [Are we] in the ballpark here? Are we (pause) no.

TA: I think you are not doing it quite right.

S1: OK

TA: |What is—| how did you measure this [...]?

S?: |I'm not sure—|

S?: For normal?

TA: No, [it's] angle of incident— angle of incidence.

S?: Oh, this is uh, 110. (pause) That'll be uh the normal.

(pause) This angle between the incident angle must be 20

degrees.

TA: Oh yes, right. Then what about theta 2? Angle of reflection- refraction.

S?: That'll be between this and where it came out.

TA: Um let's see. But ahm the definition of angle of incidence and angle of refraction is, like this. Can I use your pen? (pause) So, here is the surface, here is normal to the surface, =

S?: [...]

TA: = then the beam comes in through this surface and bend like that. This is theta 1 and this is theta 2. Then this is angle of incidence, this is angle of refraction. =

S?: [...]

TA: = So what you measure is this. =

S?: OK

TA: = So, in any case, theta 1 and theta 2 should be smaller than 90 degrees.

S1: [...]

S2: So you can't have a subtraction?

S1: |So you measure| this from this direction?

TA: Sorry?

S1: Like, if you |have| this, you measure out from the normal.

TA: Yes.

S1: [And that], wherever that is. [I don't see it.] Maybe

46:56 S1: You have to use the critical angle- the-

TA: Critical angle?

S2: For the incidence? Angle of incidence?

TA: What you have to do is just measure it. You don't have to calculate anything for this. And later on after you've got sets of data, then you will have to calculate it.

S2: [Where's the-]

TA: [You don't...] First you have to measure those two, and then you have to define new variables, and then those new variables should tell you something physical, and you have to [find] it for yourself.

S2: We use, ah, we just use these two to get these two.
TA: Let me see. (pause) Yes you can do that, but you
better do this because it's very confusing

Tape: TA2 Side B

0:15 S1: These two, from 200 to

S2: Let me see a sec, that's 187.

TA: 187? So-

S1: And this is the normal which I could just-
200's the normal so I can know this, right?

TA: That's right.

1:03 S1: Can you help us, does this need to be out here?

We have to take this out, don't we.

TA: You have to take it out.

S2: That's what we wanted to know. Ready? Oop. You
gotta- see you gotta lift here, you gotta undo
the bottom. Ready?

1:33 S1: OK then we do this 50 cm from 44 cm so it should
be 94, correct? Am I right?

TA: Yes.

2:10 S1: That's too many? Right there. There, that's
good.

S2: 84

S1: OK

TA: Then the number of spots just becomes three.

S1: [...] That's sweet.

TA: Let me see, let's just make this [like this].

S1: That's good. Now I wanna know focal length of the
lens. Focal length would be [as far as this is],
isn't it? Isn't that the focal length?

TA: No.

S1: What IS the focal length?

TA:What is the FOCAL LENGTH?

S1: Right.

TA:Uh, what do you mean by THIS is the focal length? That's that lens. Only lens have focal length.

S1: All right. So it must be the difference between these two.

TA:Yeah. Anyway, what you have to do is make parallel light. And then, the parallel light should come through this lens, and then they have to focus. Then that's focal length. If they're well focused. But this is not parallel light, so you have to make it parallel.

S1: Parallel. I don't- I don't know, what, you mean.
(pause)

S2: Oops. I think I don't want to break this.

TA:Did you break it?

S2: No, I said I don't wanna break it.

S1: It doesn't even go down that far.

TA:Let me explain what the focal length is and then you figure out focal length

S1: All right.

TA:If there is a object which is- which is infinitely far away, this is infinitely far away and there is the lens and

S1: Is this your object?

TA:Sorry?

S1: This is the object?

TA:No, there is no object here. The [beam] itself is the object. And a focus over here then this is focal length and the object should be infinitely far away. For this case the parallel light means- anyway, what this lens is focusing is the light from this object reflected on this object. And for this case this light is replaced by the laser beam. And you have to make the laser beam parallel, and then make the parallel lights go through this lens and focus, in 5

centimeter, for example, yeah, the focal length is 5 centimeter. And it's in this case 10 centimeter.

S2: So we take this out and [...]

TA: So first, what you have to do is make this parallel light. This light is diverging now.

S1: Right.

TA: So you have to make it parallel light with this lens.

S1: With that lens.

TA: Yeah.

S1: You just set it in here like this? ['cause that's] not gonna-

S2: How do you know how far away to make it- put it, you know, to make it parallel?

TA: Um, you can do that by, by measuring the interval of this width of this light. I mean,

S1: Give us a clue because we're gettin'- we're not gonna get it right. 'Cause we aren't gonna- 'cause, first of all, I can't even fit this in here so it works.

S2: Would it have to be like, 50 centimeters since that's what it- the lens says?

TA: Why don't you [...]

S1: Why don't we (pause) OK.

TA: [...] there [...] This one should be placed here.

S2: So it's 50 away, isn't it?

TA: 50 away? Did I say that?

S2: Oh, it's 50 to that lens. It's 50. So that one's [...]

TA: And how far this should be?

S2: It doesn't say. Just as far as it has to be so that [...] working [...]

TA: Then see, what you have to do is check with light. Here, the width of that is about a centimeter, here that's more than 5 centimeters. So you have to focus it a little bit and then make a parallel light. OK?

S1: All right.

7:32 S1: I don't understand what's [...]– what they're looking for.

(pause 12 s)

TA: Did you draw a graph?

S1: We did.

TA: What is this? This is angle of [incidence?]

S1: [Incidence.] This is angle of refraction.

TA: I don't believe it. It shouldn't be straight line.

S1: It should be?

S2: Should be?

TA: It shouldn't be, no. They're not proportional other, are they? 20, 15, 40, 27 [...]. Actually the line goes like this.

S1: It should bend? OK. Well, this– this one did bend. [We could make that one]

TA: OK, but, if it bent, you cannot analyze this statement because the slope changes. And you cannot find the slope because it changes. Without knowing calculus. And this course is not calculus based so you have to=

S1: [So–]

TA: = [find] the straight lines, by using another variable.

S1: It's supposed to look like that?

TA: Yes, but that tells you nothing. What you have to do is defining two new variables.

S2: [...]

S1: the what?

S2: The slope [...]

9:51 S1: Where are we supposed to set this up? OK, if we have this like this, and uh, I mean this is the relationship between these. I mean this is. These would be, otherwise [...this factor...] and this here, index over the refraction of the [...] plexiglass, =

TA: Yes

S1: = these should be close to each other. So that's like a linear equation. Well this would be like X [...] and this

would be X and this would be like uh some [...] distance away or something like that.

TA: Right, that's right.

S1: But I don't see how you would graph that [...].

TA: First, you have to—

S1: 'Cause this is gonna end up—

TA: you have to put sine theta one is equal to Y and sine theta two be equal to X , and then write down those two numbers here. And then, you can— you can draw a |graph| with Y versus X .

S1: |Yeah,| right, but—

S2: What would be the [...]

S1: Yeah, how do you get— OK, nevermind.

TA: How do you get what?

S?: sine theta.

TA: Theta one and theta two, those are not proportional to each other, but, Y and X are proportional to each other. So the slope or slope inverse is index of refraction, depending on how you choose your axis.

S2: Theta one over theta two would be [...]

S1: So we gotta make, (tap tap tap) all these thetas into Y s or sine theta into Y ?

TA: Yes.

S1: Sine theta?

TA: Sine theta one and sine theta two. Why? Why do you have to do this? Do you understand?

S1: Well you can't graph this.

TA: Sorry?

S1: You have to convert this to linear.

TA: Yeah. That's the point. You have to find the linear relationship.

S1: I should know all this junk.

12:18 S1: [...] rotated this. That's what you're supposed to do, right?

TA: Did you rotate this?

S1: This. Is that right?

TA: No.

(walk over to table)

S2: What're you doing?

S1: He said you don't rotate it.

S2: It says right here to rotate it.

TA: Rotate what?

S2: That thing. To make sure [that thing] get far enough apart.

TA: For what?

S2: Huh?

TA: Rotate this for what? You mean rotate this?

S2: Yeah.

TA: Oh, may- maybe you have to rotate this to make it parallel. That's all. After that you have to, (pause)

S2: That's what we just did! (laughing)

S1: And then you- I asked you if you rotate it and you said no! So then I just put it back?

S2: Yeah, put it behind there.

S1: Will you tell us then, 'cause we just- after this we don't know. (pause) How far? (pause) I don't think it's really affecting it that much.

S2: yeah

S1: OK tell us what to do now, 'cause we don't- we- we're trying to figure it out but we can't.

TA: You- you cannot figure out what?

S1: What we're supposed to do at all. Nobody can figure this out.

S3: We got it! (laugh)

S1: What are we supposed to do, what are we supposed to be measuring?

TA: OK. Did you make a parallel light? Is this light parallel after this lens?

S2: [...]

S1: [...]

S2: [...] what?

TA: Yeah, this is parallel. That means the object is infinitely far away. There is not object, but=

S1: OK

TA:= the beam represents object which is far away. But, if you put this lens here - I don't know

the focal length of this

S2: It says on the side of it there.

TA: Ten?

S2: Ten.

S1: Oh! Do you want to— just one and you want this distance.

TA: No, I want—

S2: This distance would be ten.

S3: You see, he wants this distance.

S1: What distance?

S3: [...]

TA: This distance. Distance between lens and screen.

S1: OK. I've got it. Here's the screen.

S2: Here's the screen [...]

S1: OK, thanks.

15:01 TA: What you have to do is finding the relationship between theta one and theta two and you— you got the values, which it satisfies, the law of nature. OK? You want to know the relationship between those two.

S1: Between theta one and theta two?

TA: Yes. So, for example, if you draw a graph, like you did, theta one versus theta two, then you will get something strange. Then you can't analyze data because that does not show any proportionality. But, if you think about Snell's Law, sine theta one is equal to sine theta two, is a constant, so you will immediately find out that, sine theta one and sine theta two are proportional to each other.

S1: So you should— we should graph sine theta one and

TA: Yes, that's correct. And then you are— you're supposed to find the values which are un- invariant under those changes.

S2: Oh, and we just graph the sines of them? OK.

S1: Yeah, instead of these we graph the sines.

S2: So I don't use the index of refraction. Well

this is close.

TA: Then how— how can you find the index of refraction by using that graph?

S1: By using this one, or the one we're gonna draw?
(students laugh)

TA: The one you're gonna draw.

S1: Oh. I don't know, but I'll tell you after I draw it.

TA: OK.

16:40 S1: See, this should [come] up the side ought to make this (pause) and uh (pause) See, these things are all common with that 1.53, so this should come out um here. But see if you do that, that's gonna end up straight.

TA:[...]

S1: Should it?

TA:[...] I don't understand.

S1: Well, if we got it.

TA:[...]

S1: Yeah, 'cause this is one, so we got this=

TA:Oh

S1: = equal to this times this. Now, take the sine of theta.

TA:Yes.

S1: So if we plot— if we plot this, it's gonna end up a line. Instead of a [...]. Is that what we're supposed to plot?

TA:Yes.

S2: Use this [...] this angle [...] this is gonna be a line though.

S1: But I thought it wasn't supposed to end up a line.

TA:You're— you're supposed to [...] a straight line.

S1: Oh really?

TA:Yes.

S1: Oh. Well I guess that's [...]

TA:Because this is a linear equation Y is equal to AX, A is the slope.

S1: I didn't know it was the slope. (mumbling)

18:31 TA: Oh, did you find the index of refraction as 1.7?

S1: using the slope to change

S2: The change in Y over the change in X over this?

S1: Can you do it that way? Or they- or they want it the [...]

TA: Yes. That is what you're supposed to do, but, that's quite different from these directions.
(pause) Can I see the graph?

S?: Yeah.

(pause. Another student comes up to the TA with a question.)

S3: Is the focal length supposed to match up with the number [on] the lens?

TA: Match?

S3: Is it supposed to be the same? If it's a five centimeters, is it supposed to be five centimeters apart?

TA: Yes.

S3: OK

(back to other two students)

S1: I don't know, it's pretty far off.

TA: This slope is not- this slope is not 1.7 that's (short pause) point 7, isn't it?

S1: Yeah.

TA: And the inverse of that is the same as index of refraction because you set this axis as sine theta one instead of sine theta two.

20:00 S1: [Well] to get the slope I just- I took the difference from this divided by the difference from this. I don't know why I got, like that. Unless I have these axes reversed. This is the Y and this is the X?

TA: You don't have to reverse these axes. After you find the slope, you have to inverse this [...]

S2: Inverse=

TA: Yeah
S2: = the slope?
TA: Yeah, no problem.
S2: So [...] graph to have X over Y?
TA: Yes
S2: [...]
TA: Yes
S2: OK
TA: And I think this— this line should pass the
origin.
S1: Oh [...] I didn't set it up that way.
S2: It's pretty close...

21:03 S1: We reverse these, and then we should get the right
index of refraction.

TA: Yes

S1: OK

21:11 S1: See you next week, Buddy.

TA: See ya.

21:57 S1: Is that right?

TA: Yes.

S1: OK.

[...]

TA: You got .65?

S1: Yep.

TA: That's not the index of refraction, is it?

S1: Is it? No.

TA: No.

(S1 laughs)

S1: Index of refraction is 1.4.

TA: [But that should] represent index of refraction.

S2: Oh wait. It's upside down. (laughs)

TA: Yeah that's right.

S1: Thanks, Dude! (S2 laughs) Invert it! Oh yeah,
there it is!

S2: Inverted slope. I knew I was right. It had to be!

- 23:33 S1: I had my numbers wrong. It could be my
[handwriting] (laugh) This is 5. [It's]
one five seven then
TA: One five |seven|
S1: |For Snell's-| for Snell's Law then? It's still
high but,
S2: It's a lot closer than it was.
S1: One of these- something [is...]
S2: One of these must be off a little bit.
TA: Is that- is that number from the slope of the
graph?
S2: Yeah. Using instead of Y over X using X over Y.
S1: Yeah see, I set up my graph so that I have X
here and Y here.=
TA: Yes
S1: = So the slope is already going to be the inverse
slope, isn't it?=
TA: Yes
S1: = by setting it up that way?
TA: Right. And N2 is index of refraction of the
plastic[s], right?
S2: Hm?
TA: N2 is index of refraction of this material?
S2: Two?
TA: And N1 is index of refraction of air?
S2: (mumbling)
S1: So this-, we'd still be using the graph, to use
Snell's we'd have to, use the index refraction
for air and the index refraction for the
plastic?
TA: Yes, |that's right.|
S1: |To get B?| OK. [...]
- 25:54 TA: [Which is the angle of incidence] is 90 degree?
S1: Yeah

TA: This is angle of incidence not angle of refraction. (pause) What is angle of refraction? What is angle of incidence? What represent angle of incidence?

S1: The angle of incidence?

TA: Yeah

S1: That's where it um [it hits the surface (pause) which is)pause)

S2: [Yeah, [when] it hits the surface

TA: This is the angle between the normal to the surface and the incident beam. Right?

S1: So the-

S2: So the um this is [315]

S1: It would be a hundred and 40.

S2: Oh, you're right.

S1: Zero and 315 is 45.

TA: Yeah. 45 is right. But this is strange because your critical angle of incidence is wrong, but your index of refraction is right.

S1: I was just guessin' at the index of refraction! (laughs)

TA: Hm.

S1: But it is right?

S2: That close [we got that]

TA: That's close.

S2: [[...] 45 degrees?

S1: [I just put 1.4 'cause we were close.

S2: So then you take sin of..

TA: Then what is- what is the uh angle of refraction? For this case?

S1: The angle of refraction?

S2: For this case up here? [It's] 180 degrees.

TA: No, I mean for [this]

S1: One.

TA: For [...]

S2: Oh, 225.

TA: 225?

S?: Yeah

TA: No

S?: For the one- the one where it disappears?
 TA: Angle of refraction is always with respect to the normal to the surface, right? This is normal to the surface.
 S2: Yeah
 S1: Oh
 S?: |Then what is-|
 TA: |So what| could that mean?
 S2: Then that's 90 degrees.
 S1: Then that's 90 degrees.
 TA: 90 degrees.
 S1: Yeah.
 TA: Right. So you get two- two variables. One. I mean index of refraction of air is one, and index of the refracted- refracted, angle is 90 degrees, so $\sin \theta_1$ is one.
 S1: 1.41
 S2: Look at that
 S1: Hm. I was only off by a hundredth. Not too bad for figuring in my head, is it.

28:30 S1: In column four-
 S2: You don't wanna know!
 S1: Column number four
 S3: On mine it was the last one.
 S1: This one and this one I think weren't right. I don't know.
 S3: I got 1.5 on my second and third and 1.42 |...|
 S2: |Yeah but this- they want these numerical [...] or they want us to [try] this one to that?
 TA: These are from graph |or-|
 S2: |Yeah|
 S3: Right
 TA: Then you got straight line. How can slope change?
 S3: I don't know, but mine did.
 S2: Someone didn't draw a very straight line.
 (laugh)
 S1: It's not perfectly straight.

S2: It's a line that best fits.

(laugh)

TA: Ohh

S2: Does that work?

(laughs)

TA: This slope should be close to=

S2: slope |of 1.5|

TA: |= all the time. | Because even though there are
some errors, as long as you draw a straight line-
definition |of| straight line-

S2: |Well see,| when you're figuring all these,
shouldn't you just like pick two points and do
it? And- but when we did it, we did all the
different points, so

TA: To be more accurate, you |have to=

S2: |be farther apart?

TA: = take these two points, and then find the slope,
and then that's the slope of all interval.

30:20 TA: Is this the slope?

S1: No, this is what I had, but for- for that I
think [...]

S2: This is my slope on this um I get a different
numbers, but

TA: The index of refraction should be greater than
one or smaller than one, what do you think?

S1: Greater than one?

S2: [...] index of refraction's [...]

S1: [So that] should be greater than one?

TA: Yes, that should be greater than one or smaller
than one.

S1: |Greater| than one.

S?: |Greater|

TA: Now, how did you find this?

S1: I got it from the write-up.

S2: The index of refraction for this? [Naw] it's [...] one
and then you take a

S3: I just put the first two [...] .
[...]

- S?: I didn't figure it out though.
- TA: That's strange. Why is this number divided by that number?
- S2: It's supposed to be this number.
- TA: Then its [coefficient] should be that number.
- S2: Right, that's [what I was saying] one fifty-two [over one fifty]
- TA: Oh.
- S2: And you used the write-up.
- S1: Huh?
- S2: You have to use [...instrument...]
- TA: You used your graph to get these number?
- S1: No, I didn't use these numbers. [...]
- TA: Then your number is different from his number.
- S1: [...]
- S2: I got a different- I used different [...]. I did my [...completions] or whatever, let's see
- S1: This number should be the same as this number?
- TA: Yes, they should be the same as these.
- S1: Oh, well, maybe I should just change this one [...]
- S2: [...], but if this is supposed to be linear, we get different slopes, right?
- TA: They're supposed to be the same.
- S?: Supposed to be the same
- TA: They're different because of errors. I don't understand how you get this, you just divide this number by that number?
- S1: Yeah- No, I didn't get this.
- TA: You didn't get this?
- S1: Huh-uh, I used [that if I can find it somewhere] earlier. That's what it is.
- TA: And did you use [the slope of this-]
- S1: [That's what it is, from this]
- TA: Did you use the slope of this graph to get the, =
- S1: index of refraction?
- TA: = index of refraction? Yes.
- S2: We have to use the slope of this?
- S1: See, I just-
- TA: Yes, that's right.

S1: I a- assumed we were trying to find the index of refraction from- from earlier, which is for uh what's it [...] and I put 153 'cause that's what we had out of the write-up.

TA: H|m.|

S1: |To| begin with on the pre-lab. That's not what I |figured. |

TA: |Oh. |

S2: We use any two points out of this, right? Sir? We use any two points to get the slope?

TA: Yes.

S2: So if we use any two points, then this would be different from that one.

TA: Yes.

S2: 'Cause I used these two |[...]|

TA: |The slope is not necessarily the same as index of refraction. Maybe the inverse of slope is refraction coefficient.

S2: 'Cause I used the first- this one, these two numbers. So it would be [kind of] different, right, if I use[d] any two points from this line?

TA: This only represent one point here, and you have to take any two of those four sets of numbers, that means either you take this set or that set,=

S2: Right

TA: = or something else. But as long as you draw a line here, you have to choose two points on the line.

S2: OK, I got it [...]

34:21 S1: Reflected goes where? What angle?

S2: Umm 320

(pause)

S2: It's reflected.

S3: I know.

S1: OK, and what is the refracted?

S3: (very softly) hmm [170]

S1: What, about 160?

S2: One seventy-three.

S3: OK,=

S1: OK

S3: = what's this?

TA:Wait a minute. This should be overlapped.

S1: They should be

TA:You're- you're trying to find the critical angle, aren't you?

S3: Right.

TA:So, maybe you should turn this to the round surface.

(laugh)

S1: Thanks, Dude!

S2: Sorry.

36:16 S1: That's about right right there.

S2: You sure?

S1: No, but

S2: "Repeat steps one, two, and three quickly to see if you have parallel rays." (pause) Looks like they're parallel at 5 millimeters apart.

TA:How can you find whether they're parallel or not?

S1: [...] Well, if you just slide it back and forth. If they stay in the same place, you know.

TA:The- they should be parallel after this lens, so you have to

S1: Oh. Well if you just slide this thing back and it stays.

TA:Are they parallel?

S?: Yep.

TA:I don't think so.

(all laugh)

S2: So what- what did we- what'd we do wrong?

TA:I don't know.

S1: Well this thing should be at 50 centimeters, right?

TA:Fifty |centimeters?|

S?: |We got it set up [...]|

S?: |You know what,| though,

S1: from the light

TA:Umm

S2: This is what- we had to do this first, I think.

TA:Yeah.

S2: Without it.

TA:Is- is this 50 centimeters?

S2: |Ohhh|

S1: |Yeah, it was.|

TA:Wait a minute. There is a [...] here. And this is, 35 millimeters; it should be 85. And then, as you move back and forth, you get some change.

S2: Think of |that!|

TA:|Maybe| [...]

S1: It's a minimal amount that-

S2: OK, so now how do we get up [to] 5 millimeters apart?

S1: Rotate the [...] by vertical axis.

S2: "Move the screen to the far end of the bench."
Left or right.

S1: Where's your- this one?

S2: Yeah.

S?: They're not separate at

S1: Well see, if we move this, that's gonna mess it up, so if you- they won't be parallel any longer.

TA:That's right.

S2: So, what do we do?

TA:You have to fix it, and then you put another lens. This is just for make the ray parallel. You're not investigating the focal length of this.

S1: OK, so this is parallel now, so we take it out?

TA:No.=

S?: No.

TA:= It should be always parallel.

S1: So now we're gonna put another one in after it.

TA:Right.=

S1: |That's-|

TA:= |You're| just using the parallel light.

S1: Yeah.

S?: Here.

(long pause)

S2: That's a whole centimeter there.

S?: There we go.

S2: Now do we measure? The distance between 'em?

TA: You have to find the focal length.

S2: OK

S1: [So] the focal length's um (flips pages) Oh that should be [...]

TA: To find focal length, you have to focus the beam.

S1: Oh, OK. Then that'd be the- to the center of the- the lens?

TA: OK, what is definition of focal length?

S1: That's the point at which the light rays converge.

TA: OK. Then, converge, what kind of rays?

S1: Parallel rays.

TA: Right.

S1: Incoming parallel rays will converge at the focal point.

TA: OK then what about diverging lens? For diverging lens, [you]- what's the definition at the focal length?

S2: That's where it reaches infinity? [...]

S1: Well the focal length would be- for diverging lens- if this were a diverging lens, the focal length would be back here, wouldn't it?

TA: Yes, that's right. But how do you find it?

S1: By bringing the in- converging, rays, and when they go out parallel, =

S2: Yeah

S1: = at the point from convergence to the point at which they go out parallel, that would be the focal length.

TA: Yes, that's right.

S1: So do I win?!

(laughter)

TA: Yeah

41:35 S1: Which do you feel is more accurate? The one we did before [...]?

TA: I told you that uh, angle of incidence and or angle of refraction always should be equal or less than 90 degree. How can they be greater than 100?

(pause)

S1: I dunno, she did the math.

(laughter)

S2: Thanks!

S1: Oh you know, we have to subtract this from 180, don't we. So it would be 45 degrees.

TA: Yes.

S2: Probably.

TA: Probably.

S1: Heh-heh-heh! I shoulda done the math.

(S2 laughs)

S1: Just kiddin', just kiddin', relax.

S2: I took it from zero. I'm sorry.

S3: So it's still gonna be the same [...] Five hundredths of a fraction, it's not gonna change.

S1: Well, I don't care.

(laughter)

S1: [That's] not the important part. The important part is we have nine minutes left.

S2: I think that Snell's Law,

(laughter)

S1: "If Q, re- give the reason or reasons for your choice."

43:20 S1: Why won't [the] ray fit!

TA: There's no ray? Is it on?

S2: It should be on this way? There.

S1: Ah-hah

43:41 S1: OK, so it went from a- from a- a- a solid

point to a dull point.

S2: From a sharp, small point, to a-

TA: If this angle is 45, is [this] still [...]?

S1: Yeah

S2: Yeah

TA: [...]

S?: [...]

TA: What's the formula [defined] now [for] the index of refraction?

S2: OK. [I'm gonna] use Snell's Law anyway.

S3: Yeah

(pause)

S1: We had to take, let's see, (pause) |this-|

S?: Is that the |sine| of 45?

S1: Yeah, divided by the other one. The sine of 45 divided by the sine of uh=

S3: 40

S1: = 60

S3: 30

S1: Y 40?

S3: [...] right here.

S1: Oh OK

TA: Y is 40?

S1: No, it wouldn't be 40. It's gonna be, 360 minus [...]

TA: What is angle of refraction?

S1: |It's from the normal, right?|

S2: |Angle of refraction?|

TA: Yes.

S2: There isn't any.

S1: Yeah there is.

TA: There isn't any?

S1: |What did you say the normal was?

S2: |[...] I said, what, the normal, which one was it, 135.

S1: The normal's 135?

S2: Mhm

S1: OK. Then it came off.

(pause)

S3: [What do I record?]

S1: |90.|
 S2: |135.| And that's why we decided it was 135, is it
 went from zero instead of 180 up here.
 S1: One point four.
 TA:1.4?
 S1: Is that right?
 TA:That sounds right, but I don't |know how you
 get it.|
 S1: |Heh-heh-heh!| I do.
 TA:By the way, |why is that| the |angle| of refraction?
 S3: |How do you get it?|
 S1: |We took-| the angle of refraction would be 90 degrees,=
 TA:Right.
 S3: |Oh that's right.|
 S1: = |and the angle-| and the other angle's what 45 degrees, so
 you take 90 by 45 and, you get one-oh- one point
 four.
 TA:Oh. Right.
 S1: Heh-heh-heh-heh!
 S2: Uhhh |[...]|
 S1: |Can we quit| now?
 TA:Sorry?
 S1: Can we quit now?
 TA:[You can go]

46:06 TA: You know what's critical angle is?

(pause)
 S1: [Well it's not gonna come out ...]
 S?: hm-hm-hm
 (pause)
 TA: Then what is critical angle here?
 S1: I have no idea.
 TA: See, the beam comes through here and then
 refracted here,=
 S1: Awright
 TA: = but there should be no refracted light
 because, refracted light, goes through this
 surface. Then the refracted light will
 disappear. To do that, you have to rotate this,

and then look at this point. (pause) It disappear around here. Right?

S1: Where, here?

TA: Here.

S1: [...]

TA: [...]. Disregard this point. This is reflected light. It disappear. So when they disappear, that's critical angle.

S1: Oh. (pause) I didn't see that.

APPENDIX B.

The Reflection and Refraction of Light

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The Reflection and Refraction of Light

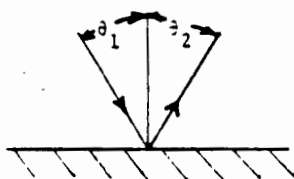
Related Reading: Giancoli - Sections 22-5, 6, 7

Pre-lab assignment: Read or scan as seems appropriate the referenced material and the experiment description. Then answer the questions that follow below.

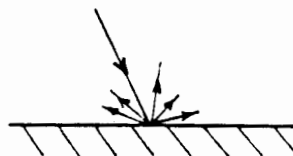
Introduction:

In most of our everyday experiences with visible light, the wave properties of light are not apparent. The description of the propagation of light in these situations, and also in many common optical instruments such as eye glasses, cameras and microscopes, involves a branch of physics called geometrical or ray optics. The simple equations of ray optics assume that light travels in a straight line unless reflected by a surface or refracted (i.e., deflected) by a change in the optical properties of the medium through which the light is passing. Ray optics ignores effects such as diffraction and interference which result from the wave nature of light.

Reflection of light: The term specular reflection refers to reflection from a smooth surface, while diffuse reflection refers to reflection from a surface that is relatively rough.



Specular reflection



Diffuse reflection

Figure 1

For the case of specular reflection, such as from mirrors or ordinary glass surfaces, a reflected light ray leaves the surface in a unique direction. In particular, the reflected ray

1. lies in the so-called plane of incidence, that is, the plane formed by the incident ray and the normal to the surface;
2. forms an angle with the normal (angle of reflection) which is equal to the angle between the incident ray and the normal (the angle of incidence).

Using the angles shown in Figure 1, this second condition can be written algebraically as

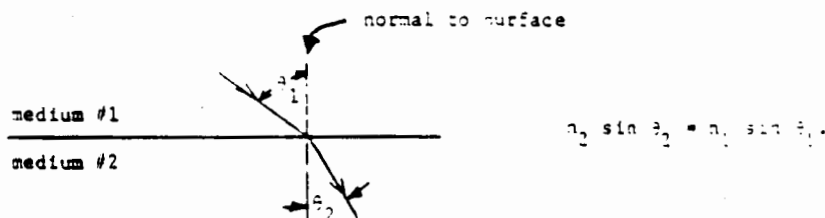
$$\theta_2 = \theta_1$$

For most surfaces, the reflection is diffuse. It is this type of reflection that allows you to see ordinary objects, including this page you are reading.

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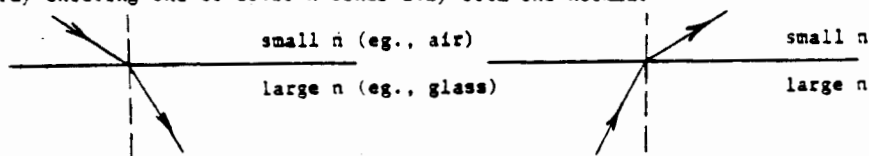
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Refraction of light: When a light ray passes from one transparent material into a second, the ray will change direction in a way described by the simple algebraic relation given below which is called Snell's law.

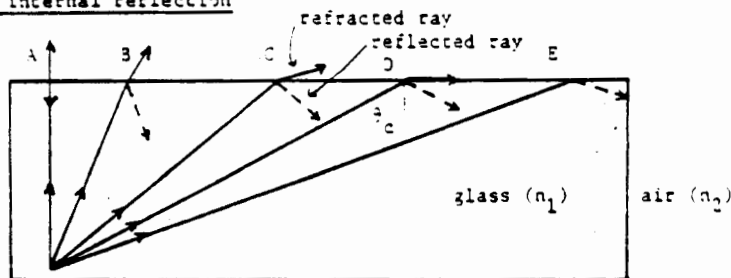


The indexes of refraction of the two materials are represented by the parameters n_1 and n_2 , while θ_1 and θ_2 , the angle of incidence and the angle of refraction, are measured with respect to the normal to the surface between the two media. If one prefers to use a different angle to describe the incident or refracted ray, then Snell's Law must be modified accordingly. Knowledge of the definitions of θ_1 and θ_2 and Snell's Law are of equal importance in predicting the direction of a refracted ray.

The index of refraction of air is approximately unity ($n_{\text{air}} = 1.000278$ for $\lambda = 500 \text{ nm}$) while that of most transparent materials is in the range 1.3 to 1.7. Note that if n_2 is greater than n_1 , then θ_2 is less than θ_1 and vice versa. Thus, a ray entering a region of larger n bends toward the normal while a ray entering one of lower n bends away from the normal.



Total internal reflection

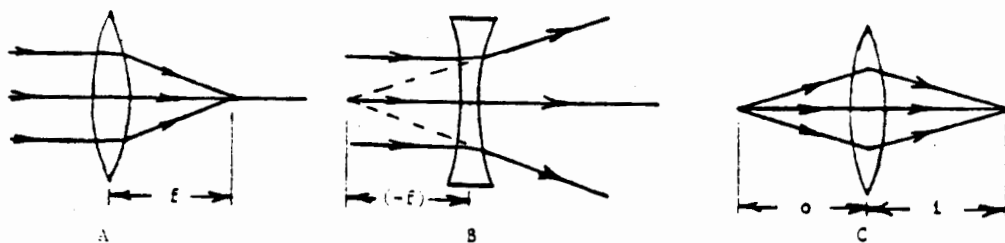


When a light ray is incident on a smooth boundary separating two transparent materials, it is generally split into reflected and refracted rays. However when the incident ray is directed toward a region of lower n there may not be a refracted ray. This situation is illustrated above. As we progress from case A to point D, the angle of incidence and the corresponding angle of refraction are increasing. At point D, where the angle of incidence equals the critical angle, θ_c , the refracted ray is parallel to the boundary. For angles of incidence larger than θ_c there is no refracted ray, and all of the incident beam is reflected from the boundary. A formula for the critical angle is obtained by setting the angle of refraction equal to 90° in Snell's law:

$$n_1 \sin \theta_c = n_2 \sin 90^\circ \text{ or } \sin \theta_c = \frac{n_2}{n_1} = \frac{n_{\text{air}}}{n_{\text{glass}}}$$

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Lenses:



The focusing properties of a thin lens are characterized by its focal length, f . The focal length of a converging lens is the distance from the lens to the point at which incoming parallel rays converge (see Fig. A). Parallel rays are refracted away from one another by a diverging lens; when extrapolated backwards, these rays appear to originate at the so-called focal point. The focal length in this case is defined to be the negative of the distance of this point from the lens (Fig. B). The distances from a thin lens to a point object and its image (Fig. C) are related to the focal length via the thin lens equation,

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

By using Snell's law, the focal length of a thin spherical lens can be related to the radii of curvatures of its two surfaces and the index of refraction of the glass. An involved derivation yields the lens-makers equation

$$\frac{1}{f} = \left(\frac{n_{\text{glass}}}{n_{\text{air}}} - 1 \right) \left(\frac{1}{R_1} + \frac{1}{R_2} \right)$$

where R_1 and R_2 are positive for convex surfaces and negative for concave surfaces.

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Reading the following reprint from the "Dear Isaac Newton" column will help you with the questions that follow.

Dear Ike:

My lab instructor told me to sit in the corner and "analyze" my data. Please give me some clues as to what she's talking about.

J. Horner

Dear Jack:

Faced with a collection of numbers, a scientist seeks to summarize in a concise way the implication of that data. Often she has the following purposes in mind:

1. to test the degree to which the data set is represented by a particular equation and to characterize any deviations from that equation. Often the equation used is suggested by the applicable theory.
2. If no reliable theory is available (eg, complicated secondary effects may make use of simple theories unrealistic), to find an equation that reproduces the trend of the data. Such an equation is called empirical, meaning it is based solely on experiment.
3. to determine the most accurate values possible for any constant(s) in the equation.
4. to obtain reliable estimates of the uncertainties in the results.

The methods used can be graphical or numerical, and often involve trial and error as well as common logic. The common graphical techniques for analyzing a set of data for two variables, y and x , include

1. a simple plot of y vs. x . If the points are scattered all over the page or lie along a horizontal or vertical line, y and x are unrelated, or as is said in fashionable circles, are uncorrelated. If the points lie along a straight line which is not parallel to one of the axes, y and x are linearly related, ie, $y = mx + b$. If the line goes through the origin, y and x are directly proportional to one another, ie, $y = mx$.
2. a graph which includes both the data points and a curve representing an equation; if the points lie (within the estimated uncertainties) along the curve, then it can be said that the equation represents the data. If some or all of the points do not lie so, the discrepancy will be visually apparent.

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3. plotting the data so as to get a straight line. Even if y and x are not linearly related, one can strive to find functions of y and/or x or choose nonlinear graph paper (eg, log-log paper) such that a straight line results. For example, if a plot of y vs. x^2 yields a straight line, then we know that

$$y = ax^2 + b$$

This is a very common technique; a few other examples are tabulated below.

Plotting method that yields a straight line	Functional relation that exists between y and x
plot y^2 vs. x	$y^2 = ax + b$
plot y vs. $x^{1/2}$	$y = a\sqrt{x} + b$
plot $\log y$ vs. $\log x$ or y vs. x on log-log paper	$y = ax^b$
plot $\log y$ vs. x or y vs. x on log-linear (semi-log) paper.	$y = ae^{bx}$

Numerical methods include

1. direct numerical comparison of the data with a function. Since this often can be done in a way which does not require the knowledge of all the constants involved, this approach is more useful than it may sound. For example, the period, T , of a pendulum is expected to be related to its length, L , by the expression

$$T = 2\pi\sqrt{L/g} = (2\pi/\sqrt{g}) \sqrt{L}$$

Hence, if the period is measured for various lengths, we expect the ratio T/\sqrt{L} to be constant and to have the value $2\pi/\sqrt{g}$. The degree to which this ratio is not constant indicates the minimum level at which unwanted secondary effects (measurement errors, air drag, etc.) are affecting the results.

2. least-square fitting procedures. This method yields more comprehensive results than graphing techniques, but requires more expertise and effort to be used correctly. As computers become cheaper and smaller, these procedures will likely become more common.

(You need hand in only pages 6 and 7 at the beginning of your class.)

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NAME _____

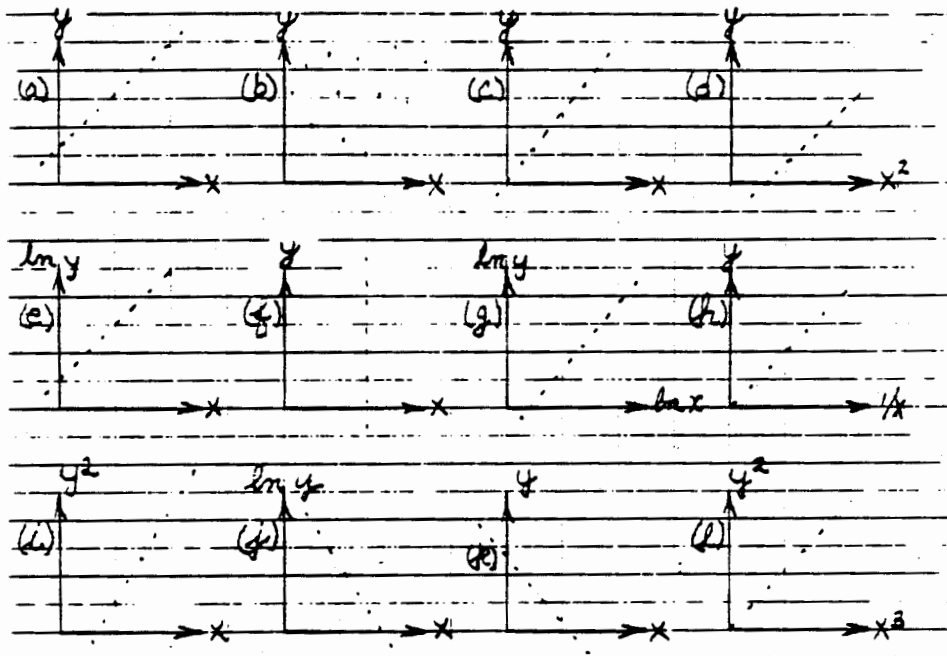
I believe it's time to close this letter and let you up for air. The topics of least-square fits and uncertainties, which I'm sure you are dying to hear about, will have to wait for another day.

Good luck with your data.

L.N.

Exercise #1:

For each of the graphs shown below, state the functional relation between y and x that is suggested by the data.



- | | |
|----------|----------|
| a. _____ | g. _____ |
| b. _____ | h. _____ |
| c. _____ | i. _____ |
| d. _____ | j. _____ |
| e. _____ | k. _____ |
| f. _____ | l. _____ |

Exercise #2:

A light beam passes through a semi-circular shaped piece of plexiglass as shown.

- a) What is the angle of incidence at surface #1? (Please use the standard definition of this angle!)

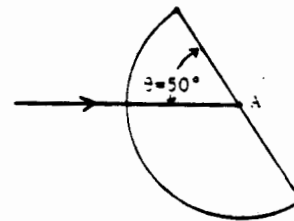
angle of incidence = _____

- b) As shown in the figure above, why does the light beam not change direction at surface #2?

- c) What is the index of refraction of the plexiglass?

index of refraction = _____

- d) Consider the same plexiglass block oriented as shown at right. When the incoming beam strikes the flat surface at the central point A, it is split into reflected and refracted beams. Sketch these two beams giving in each case the angle each makes with the line of the incident beam.



- e) If the plexiglass block described in part (d) is rotated about the point A, for what range of angles, θ , will there be no refracted beam?

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Lab No. 10

DATE: _____

NAME: _____

LAB PARTNER: _____

The Reflection and Refraction of Light

Activities

You will observe the reflection and refraction of a laser beam, measure the change of direction of the beam for various orientations and compare these results to the relatively simple laws of reflection and refraction. You will prepare a set of parallel laser beams and observe the focusing properties of various lenses with these parallel rays, determining the focal length in each case. A brief outline of the lab activities follows.

- I. Preliminary preparation of the apparatus
- II. Reflection and refraction - a qualitative look
- III. Specular reflection and refraction - some quantitative results
 - a. the law of reflection
 - b. Snell's law
 - c. the critical angle

APPENDIX. Multiple rays and lenses

Major equipment items

1. A neon-helium laser with a total radiated power of 0.5 mW (0.5 milliwatts)
2. Optical bench with assorted accessories and lenses
3. A ronchi ruling with 300 lines/inch for producing multiple light beams.

Laser Safety: Although the power of the laser you will be using is too low to be used for burning, cutting or drilling of materials, it is powerful enough to be of some risk to the retina of your eye. Do Not Stare Directly Into The Laser Beam Or Its Bright Reflections. Be sure that your laser is not aimed where it might strike someone's eye. A good rule to follow is to have your laser aimed at a nearby screen or wall before turning it on.

This week's experiment is quite extensive. Depending on your familiarity with the topics and your own experimental expertise, you may or may not finish all the parts of the procedure. If you do not finish the lab and you have done your best, please relax. You are in class to learn, not be the fastest optical bench jockey in town. Use reasonable care with those measurements you do finish; please, do not rush or dawdle along!

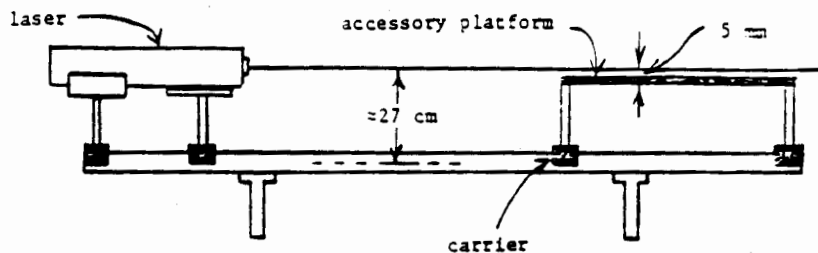
Some Reminders: As with all records of laboratory work, you must

1. use pen (except perhaps when making graphs);
2. preserve your original data records. Hence, include with your report today the original sheet on which you trace light rays; sign and date this record.

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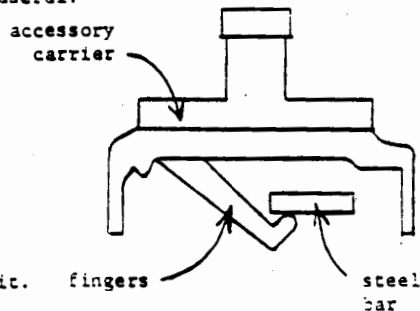
I. Preliminary preparation of the apparatus

- I(a) Alignment of the laser: With the laser mounted as far to the left as possible, check to see that the beam is parallel to the bench, adjusting the height of the laser stands as needed. The beam should be about 27 cm above the central depression in the optical bench.

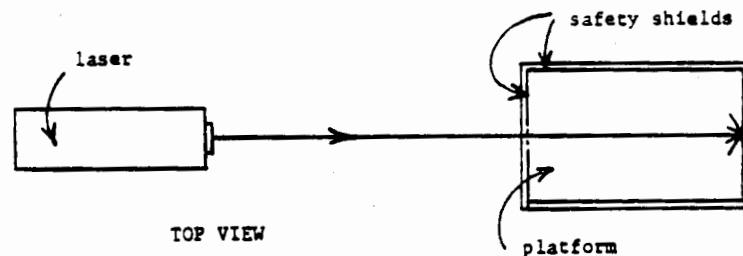


- I(b) Accessory platform: Mount the accessory platform at the right end of the bench, adjusting its height so that it is uniformly 5 mm below the laser beam. For elevation measurements, the aluminum block with a piece of graph paper attached is particularly useful.

An important note: For reproducible results, you will want the platform to be held rigidly in place. After tightening the two thumb screws on the accessory carrier under each end of the platform, the platform should be firmly in place. If you are able to lift up either carrier, then the steel fingers shown in the figure are not in their proper place under the rectangular steel bar affixed to the optical bench. Seek aid if you need it.



- I(c) Safety shields:

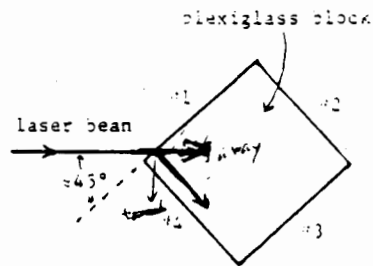


So that there is a barrier to stop the laser beam reflected by objects that will be placed on the platform, insert a strip of sheet metal in each of the slots machined along the edges of the platform. One strip should have a notch which allows the beam to enter the region over the platform. These metal shields will help protect your eyes and those of others in the room.

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II. Reflection and Refraction - a qualitative look:

Place a piece of paper (see end of writeup) on the platform. Then lay a rectangular piece of plexiglass on the paper and observe the reflection and refraction that occurs at various surfaces for various orientations. After you have experimented for awhile, position the block such that the laser beam strikes one surface at about 45° near a corner as shown. Trace the outline of the block, and trace the paths of the incident, reflected and refracted rays outside of the block. When you are done, remove the block and trace on the paper the path the beam must have had within the block. Attach this drawing to your or your partner's report.



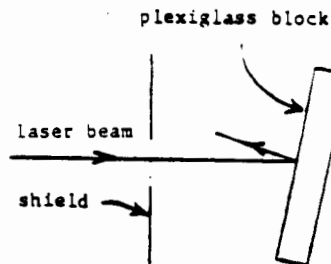
Question #1: Does the ray entering the block at surface #1 refract toward or away from the normal to the surface? Circle one: (toward, away from)

Explain this result: _____

Question #2: Does the ray leaving the plexiglass through surface #3 refract toward or away from the normal: (toward, away from). Explain this result: _____

Stand the plexiglass block up on one edge, and reflect the laser beam back toward the safety shield on the left.

Question #3: How many reflected beams can you see striking the shield? Look carefully.



Explain the origin of each: _____

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Try reflecting the laser beam from a white card.

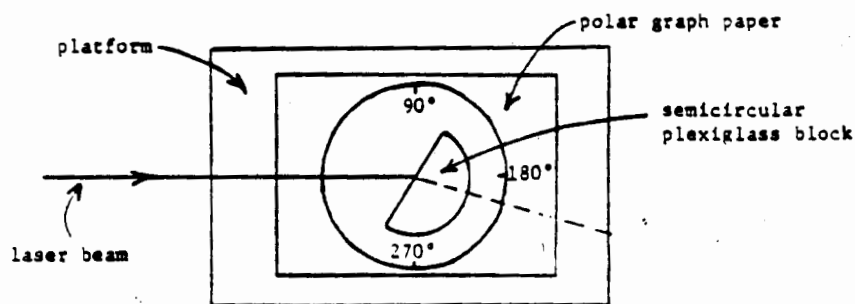
Question #4: How many well-defined beams reflect from the white card? _____

Question #5: Is any light reflected by the white card? _____

Question #6: When viewing from an arbitrary angle, for which type of surface (plexiglass or white card) is it easier to discern the place where the light beam strikes the surface? Explain if you can.

Question #7: Reflection from a smooth surface such as that of polished plexiglass is referred to as _____ reflection while reflection from a rough surface such as that of a white card is referred to as _____ reflection.

III. Specular Reflection and Refraction - some quantitative results: By using a protractor and ray directions recorded as you did in the previous section for the plexiglass block, the laws of reflection and refraction can be tested. A more direct procedure involves using polar graph paper and, for refraction studies, a semicircular piece of plexiglass.

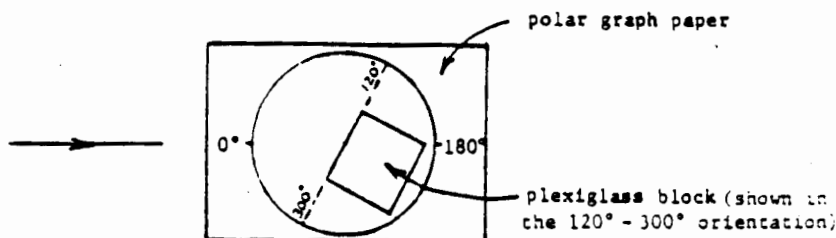


If an incident light ray strikes the center of the flat side of the block as shown above, then the refracted ray within the block will be normally incident on the curved surface and hence suffer no change in direction as it exits the block. Thus, the ray changes direction only once for this arrangement, that is, when it enters the block. The relative directions of interest can be directly noted and read from the polar graph paper.

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III(a) The Law of Reflection: Use the procedure outlined below to measure the angle of reflection for various values of the angle of incidence.

(1) Carefully position the piece of polar graph paper on the platform so that the laser beam passes directly over the 0° and 180° markings, with the 0° mark located on the left. You will find the metal block with the attached grid helpful when aligning the paper and later when measuring various ray directions. When the paper is properly aligned, tape it into position.



(2) Study reflection from a polished edge of a plexiglass block. Place the block so that the front reflecting edge crosses the exact center of the paper. For the various orientations of the front surface listed below, observe the direction of the reflected beam. Please note that a ray must pass over the center of the paper for the angular markings to be useful in determining the ray's direction.

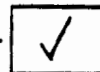
-----Raw Data----- Analysis-----

Orientation of reflecting surface	Direction of reflected beam	Direction of normal to surface	Angle of incidence	Angle of reflection
$120^\circ - 300^\circ$				
$135^\circ - 315^\circ$				
$150^\circ - 330^\circ$				

Complete the table above for each of your measurements.

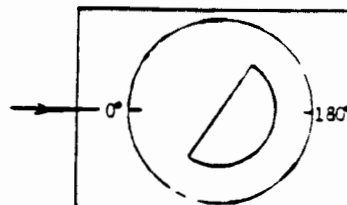
Approximately, to what level of accuracy (expressed in degrees) does your data set confirm the law of specular reflection? _____

At this point, ask your instructor to check your work.



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III(b) Snell's Law: Use the procedure outlined below to study quantitatively the refraction of light by a surface. Center the straight edge of a semicircular block of plexiglass on the graph paper. For the various orientations of the front surface listed below, observe the direction of the refracted beam. For later reference, you may wish to mark the position of the refracted beam on the paper. Remember, for accurate angular determinations by this method:



- (1) The plexiglass must be centered on the paper;
- (2) The incident beam must strike the block at a point directly over the center of the paper;
- (3) Note that you can use the beam reflected from the front surface of the plexiglass to help position the block precisely.

← Raw Data →				(discussed below) → Analysis ←			
Orientation of front surface	Direction of refracted beam	Direction of normal to surface	angle of incidence θ_1	angle of refraction θ_2	1	2	3
110° - 290°							
130° - 310°							
150° - 330°							
170° - 350°							

In considering the data above, two questions arise quite naturally:

- a) Is θ_2 related to θ_1 as predicted by Snell's Law, or does nature suggest some other functional dependence between θ_1 and θ_2 ?
- b) If the mathematical form of Snell's Law seems correct (to some level of accuracy), what is the value of the pertinent parameter in that equation, namely, the index of refraction of the plexiglass.

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Both of these questions can be answered to a satisfactory degree with one well chosen graph. Use the data above to construct an appropriate graph of your results. Then use this graph to respond intelligently to the two questions above. (Columns #1 and #2 in the table above can be used as you see fit.)

Response to (a): (Explain your answer well!)

Response to (b):

index of refraction: _____

To contrast with this graphical analysis, perform a brief numerical analysis of this data by calculating an appropriate function of θ_i and θ_r , which, on theoretical grounds, you expect to be constant. Enter these values in column #3 above and write the function calculated at the head of this column.

Comment on these numerical results. _____

Which of these numerical values do you expect to be the most accurate, or do you feel they are equally accurate? (Hint: Is refraction equally noticeable at all angles of incidence?) Explain.

Use the results of this analysis appropriately to calculate the index of refraction of the plexiglass. Use a procedure which is likely, in your opinion, to yield the most reliable value. Describe in a few words the procedure or data used.

Procedure used: _____

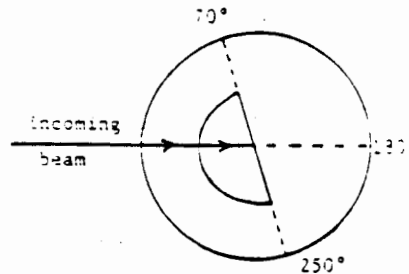
index of refraction: _____

At this point, ask your instructor to check your work.
Make corrections as necessary.



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III(c) Critical angle. The index of refraction of the semi-circular block can also be determined from the critical angle at which a refracted ray leaving the plexiglass first vanishes. Arrange the block on the accessory platform in the orientation shown at right. As before, the block must be centered on the graph paper, and the beam should strike the flat side of the block above the origin of the paper. Notice that the incoming beam will not be deflected when it first enters the plexiglass. Locate the reflected and refracted beams on your apparatus, and sketch their paths on the above drawing. Then slowly rotate the block ccw, taking care to keep it properly centered, until the refracted beam first vanishes. Record the orientation of the flat side of the block, and from this orientation calculate the critical angle of incidence and the index of refraction of the block.



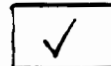
orientation: _____ critical angle of incidence: _____

Index of refraction: _____

You have now determined the index of refraction of plexiglass by two different procedures. Compare these two results and indicate which result you feel is the most accurate. Give a reason or reasons for your choice.

As you rotate the block from the 70° - 250° position toward the critical orientation, what change do you notice in the intensity of the reflected beam?

At this point, ask your instructor to check your work.



If you have any time remaining, continue on with the activities outlined in the Appendix that follows.

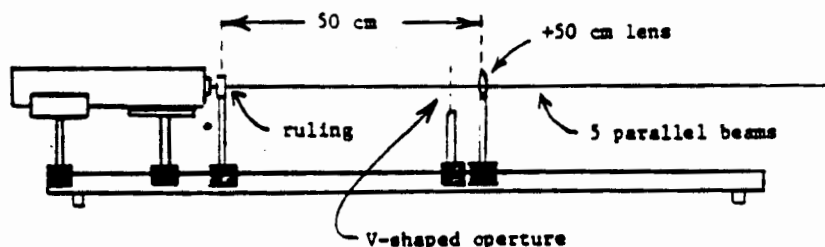
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APPENDIX.

Multiple rays and lenses

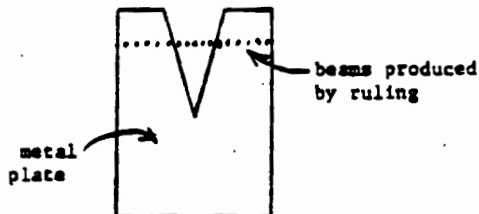
To study the focusing properties of a lens it is useful to have a set of incoming parallel light beams. We can produce such a set from the single beam of the laser by using a Ronchi ruling. A Ronchi ruling consists of finely spaced parallel slits. It uses the wave properties of light to produce a set of outgoing beams which diverge from the point where the laser beam strikes the ruling. These diverging beams can then be made parallel by using a single lens located one focal length from the ruling.

IV(a) Setup of multiple, parallel ray system: As shown below, place a Ronchi ruling, with its lines oriented vertically, immediately in front of the laser. Position a large lens with a focal length of 50 cm at a distance of 50 cm from the ruling. Aim the laser so that the multiple beam pattern is centered on the lens. (You can lower the ruling briefly to determine the true central ray of the pattern.) Remove the accessory platform.



Obtain a pattern of five parallel rays, spaced by 5 mm each, to the right of the lens by the following procedure:

- (1) Place a screen immediately to the right of the lens.
- (2) Rotate the ruling about a vertical axis until the beam rays striking the screen are separated by 5 mm each.
- (3) Move the screen to the far right end of the bench (or better yet, use a distant wall). Move the 50 cm lens slightly left or right until the beams are again separated by 5 mm at this distance also.
- (4) Repeat steps 1, 2 and 3 quickly to see that you have parallel rays separated by 5 mm each.
- (5) Mount the V-shaped aperture in front of the lens so that only the central five beams reach the lens.



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IV(b) Parallel rays and simple lenses: Mount in turn each lens listed in the table below in the path of the five parallel rays. For each converging lens use a mounted screen or scale as needed to locate the focal point and use a rule to directly measure the focal length to the nearest millimeter. For the case of the diverging lens, make a sketch of the rays and list the measurements you made to determine the focal length in the space following the table.

Nominal focal length of lens	Measured focal length of lens
+5 cm	
+10 cm	
+15 cm	
-20 cm	

Sketch and calculations for the diverging lens:

For the case of the +5 cm lens, estimate the accuracy of your value for the focal length. Explain how you arrived at your estimate. _____

At this point, ask your instructor to check your work.



If you have reached this point with a good understanding of today's activities, congratulations. You are welcome to use the apparatus to try other lens combinations or whatever suits your fancy in the time, if any, that remains.

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TE: _____

NAME: _____

LAB PARTNER: _____

Tracing of laser beam path:

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